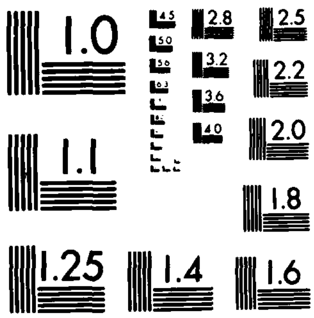
AD-A170 903 THE EFFECTS OF PHYSICAL CONDITIONING ON HEAT TOLERANCE IN CHEMICAL DEFENSE GEAR(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH M M NAUSS JUN 86 1/1

UNCLASSIFIED AFIT/CI/NR-86-108T F/G 6/19 NL

END
DATE
FILMED
9-86


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0

AD-A170 903

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFIT/CI/NR 86-108T	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) The Effects of Physical Conditioning on Heat Tolerance In Chemical Defense Gear		5. TYPE OF REPORT & PERIOD COVERED THESIS/~~DISSERTATION~~
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Michelle M. Nauss		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS AFIT STUDENT AT: The University of Texas		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS AFIT/NR WPAFB OH 45433-6583		12. REPORT DATE 1986
		13. NUMBER OF PAGES 78
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLAS
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

DTIC ELECTE AUG 1 3 1986 S D E

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

APPROVED FOR PUBLIC RELEASE: IAW AFR 190-1

Lynn Wolaver

LYNN E. WOLAVER 6 Aug 86
Dean for Research and Professional Development
AFIT/NR

19 KEY WORDS (Continue on reverse side if necessary and identify by block number)

DTIC FILE COPY

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

ATTACHED.

86 8 12 043

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

THE EFFECTS OF PHYSICAL CONDITIONING ON HEAT TOLERANCE IN CHEMICAL DEFENSE GEAR

By

Michelle M. Nauss, BSN

A PROJECT PROPOSAL

Presented to the Faculty of The University of Texas

Health Science Center of Houston

School of Public Health

in Partial Fulfillment

of the Requirements

for the Degree of

MASTER OF PUBLIC HEALTH

THE UNIVERSITY OF TEXAS HEALTH SCIENCE CENTER AT HOUSTON
SCHOOL OF PUBLIC HEALTH
Houston, Texas
June 1986

ACKNOWLEDGEMENTS

I would like to thank my instructors at the San Antonio Campus of the University of Texas School of Public Health for providing me with the background to complete this proposal. I would especially like to thank Dr. Martin Werner and Dr. John Scanlon for their helpful review and advice, Dr. Alfonso Holguin for helping me design my project and giving me the confidence to word process, and Dr. Clayton Eifler for his assistance with the statistical models. I would especially like to thank Dr. Lorin Myhre of the School of Aerospace Medicine, Stress Physiology Laboratory, for all his help and patience. I would like to acknowledge the assistance of the documents section of Strughold Aeromedical Library, Brooks Air Force Base, Texas.

THE EFFECT OF PHYSICAL CONDITIONING ON HEAT TOLERANCE IN CHEMICAL DEFENSE GEAR

Michelle M. Nauss, BSN
The University of Texas
Health Science Center at Houston
School of Public Health, 1986

Supervising Professor: Dr. Martin Werner

Today the threat of chemical warfare is real. The only effective defense is the use of chemical defense gear and gas masks. Since they render chemical warfare gases and liquids impermeable to penetration, they also prohibit sweat evaporation in conditions of thermal stress and thus, contribute to heat illness development. Historically, it has been the hot, humid tropics where United Nation's peacekeeping forces have been called, thus the use of chemical defense gear in these regions is a realistic possibility and heat illness could affect the outcome of any mission carried out there. The human body only operates within a narrow range of core temperature and heat illness is the result of a breakdown in homeostasis. Many factors influence heat tolerance, thus maintaining core temperature within a safe range. Adequate hydration, acclimitization to heat, low body weight, young age, low alcohol intake, and physical fitness all contribute to heat tolerance. This proposal attempts to look specifically at the effect of physical conditioning on heat tolerance in chemical defense gear as a possible solution to the heat stress problem noted in this gear. The subjects, basic trainee graduates attending technical training schools at Lackland AFB, Texas, will be tested for maximum oxygen uptake (VO2max) and "heat tolerance time" (HTT) in chemical defense gear on bicycle ergometers at Brooks AFB, Texas. Half of these subjects will be physically conditioned for 12 weeks. At the end of the 12 weeks, all subjects will again be tested for VO2max and "heat tolerance time" in chemical defense gear. Changes in VO2max, HTT, and body weight will be compared for statistically significant differences. Positive correlations would be the basis for further studies to determine whether the relationship was causal and if so, could be the basis for the initiation of a mandatory physical training program in the USAF.

TABLE OF CONTENTS

TABLES

INTRODUCTION

Widespread use of chemical weapons first occurred during World War I. The French introduced varieties of tear gas in the opening battles as early as August 1914. The first great gas attack was launched by the Germans at Ypres in Belgium during April 1915, and involved a total of 150 tons of chlorine. This was soon replaced by phosgene and later by mustard gas. The gases were initially released directly from the containers but were later delivered by artillery shells. The greatest losses attributed to chemical weapons occurred in Russia. One half million casualties were estimated with 50,000 fatalities. Contributing to these high losses were lack of protective respiratory devices, poor training and limited supplies.

In 1925, the Geneva protocal prohibited the use of chemical weapons. However, this did not deter the Italians from using mustard gas in a 1936-1937 war against Abyssinia. In 1936 tabun, the first nerve gas, was invented. By 1939, the Germans had begun its manufacture. Sarin was also manufactured during World War II by the Germans. After the war, large German stockpiles of nerve agents and other chemical warfare materials were seized, including the seizure of an entire tabun factory, by the Soviet Union.

During the Yom Kippur War in 1973, Soviet tanks and

other equipment, which included highly efficient chemical warfare protective devices, were captured by Israel. This spawned a renewed NATO interest in the chemical threat and therefore, increasing emphasis on chemical protection. By the end of the 1970's, an increasing number of press and intelligence reports hinted that chemical warfare agents were being used in various "minor conflicts" including the Yemen War of 1963-1967, Laos, Cambodia, and Afghanistan (Gripstad 1983).

The chemicals developed for military use are of five general groups: nerve agents, choking agents, blood agents, blister agents and riot-control agents. (See Appendix 1 for detailed explanations of chemicals used in war.) There are currently a number of chemical agents with various physical and chemical properties available for warfare. Nerve agents are of the greatest concern to the United States Department of Defense since their toxicity, rapid action, ease of storage and delivery, and low cost give them advantages over all other chemical warfare agents. A lethal respiratory dose can kill a victim in a few minutes. Sublethal exposures may result in neurological and psychiatric disorders. Detoxification of such poisoning by the body is slow, enabling a low-level concentration over several hours to have the same effect as high-concentrations of the same dose over a period of seconds or minutes.

Antidotes and decontaminants are available for protections against chemical warfare agents but are of limited use. The most effective defense against chemical warfare is the use

of gas masks and protective clothing. The standard chemical protective clothing system used today consists of a two-piece overgarment, butyl rubber footwear covers, cotton glove liners, butyl rubber gloves, a face mask and a hood. The overgarment consists of a coat and trousers made of an outer layer of nylon cotton twill and an inner layer of charcoal impregnated polyurethane foam that provides protection against vapors, aerosols, and small droplets of nerve and blister agents (Chemical Protective Clothing Systems, 1981). A major limitation is the lack of sweat permeability required to provide cooling under many field conditions of increased work or hyperthermia. (See Appendix 2 for current wear recommendations.)

Since historically it often has been the hot, humid tropics where United Nation's peacekeeping forces have been called, the use of chemical warfare gear in these regions is a realistic possibility. This would have the effect of adding environmental thermal stress to an already compromised situation. Studies directed towards the effects of chemical protective gear on performance, showed that in moderate environments most foot soldiers would become heat casualties within a certain time period (Chemical Protective Clothing Systems, 1981). Other studies involving aviators demonstrated that chemical defense gear increased rectal temperatures, heart rates, sweat rates, and caused extreme fatigue and mental confusion that bordered on tolerance limits in temperature of 27^{0} to 35^{0}C (Yates et al. 1980, Knox et al. 1982). These studies imposed a conserva-

tive amount of heat stress to insure the health and safety of the subjects and included adequate water intake. Thus the actual use of chemical defense gear would probably have a greater hyperthermic effect than the studies have indicated. This proposal is designed to determine the degree to which physical conditioning increases heat tolerance in chemical defense gear among newly recruited Air Force personnel. Results may be used to develop new strategies enabling workers to perform better and longer while using chemical defense gear.

SPECIFIC PURPOSES: To test the effect of physical conditioning on heat tolerance in chemical defense gear.

GENERAL PURPOSES: To enable United States Air Force (USAF) personnel to perform their mission faster and more efficiently, or to be able to work longer, under conditions of thermal stress in chemical defense gear.

DEFINITIONS

ACCLIMITIZATION: Series of physiological adaptations to physical work in hot ambient conditions which allow increased work capacity under those condition.

BASAL METABOLISM: The minimal amount of energy-producing activity necessary to sustain life at a complete resting state.

BASE-OF-PREFERENCE: Choice of available bases for specific career field as designated by a 4 digit number (Air Force Specialty Code (AFSC)).

BLACK GLOBE TEMPERATURE: Temperature measured with a device to measure the mean radiation from the surroundings and consists of a metal sphere painted matt black. Influenced by air movement and surrounding walls and surfaces. Air temperature and air velocity must also be computed to accurately define the mean radiant temperature of the environment.

CONDUCTION: Direct transmission of heat from the body skin to another physical substance. Must be transferred quickly to be effective.

CONVECTION: Heat transmission that is a function of the temperature gradient between the skin and the ambient air or outer clothing, and the movement of air past the surface. If the air speed is above a few miles per hour, the rate of heat loss does not increase because the air movement is not in contact with the skin long enough to conduct heat.

CORE-TEMPERATURE: The internal temperature of the body as measured at an 8 cm. depth in the rectum.

DEHYDRATION: The loss of fluid from the body due to sweating which causes the subject to be in a fluid-deficient state.

EVAPORATION: To convert into vapor. Is a function of air speed, and the difference in vapor pressure beytween the perspiration on the skin (vapor pressure of water at skin temperature) and the air.

HEAT ILLNESS: Any physical deviation from the healthy state due to exposure to high environmental temperature.

HEAT TOLERANCE TIME (HTT): Total time in chemical defense gear to reach 39^{0}C rectally when stressed on a bicycle ergometer.

MAXIMUM OXYGEN UPTAKE (VO2MAX): The highest oxygen uptake an individual can attain during physical work while breathing air at sea level.

METABOLIC HEAT PRODUCTION: Heat produced by the body as a result of food oxidation. Seventy-five percent of the energy generated is given off as heat rather than as work.

RADIATION: Emission of infrared radiation from a body.

RELATIVE HUMIDITY: The amount of moisture in the air as compared with the amount that the air could contain at saturation at the same temperature.

SWEAT RATE: The amount of the sweat lost through sensible and insensible perspiration during a given amount of time as measured by body weight loss.

WET GLOBE TEMPERATURE: Temperature measured by a bulb covered with a soft cloth soaked in clean water. Based on the principle that an exposed liquid is usually a few degrees cooler than the surroundings because of the extraction of latent heat by evaporation. After an initial drop in temperature, heat flows into the liquid from the environment at the same rate as it is lost by evaporation and, as no other heat source is supplied, the air temperature will fall. After some time, the air will become saturated by the vapor from the evaporating water because the temperature is falling. Must be kept in a moving airstream to be read correctly.

REVIEW OF THE LITERATURE

Homeostasis is the ability of an organism to maintain a stable internal environment with all the adaptive responses maintaining this stability. The protected human being can tolerate variations in environmental temperatures between -50^{o} and 100^{o}C (Astrand and Rodahl 1977). However, a person can only tolerate a variation of approximately 4^{o}C in deep body temperature without impairment of optimal physical and mental work capacity. Body temperature changes affect cellular structures, enzyme systems and numerous temperature-dependent chemical reactions and physical processes. The maximal limits which the living cell can tolerate ranges from -1^{o}C, when ice crystals form and break the cell apart, to 45^{o}C when thermal heat coagulation of vital cellular proteins occurs (Astrand and Rodahl 1977). Only for short periods can cells tolerate an internal temperature exceeding 41^{o}C, with temperatures above 40^{o} to 44^{o}C frequently causing irreversible damage, usually to the liver, kidney and brain (Buchbaum et al. 1970).

Environmental temperatures at the maximum tolerable limits are more of a problem than cold temperatures, as people can protect themselves more easily against overcooling than overheating. Thus most mechanisms for temperature regulation are particularly geared to protect the body tissue against over-

heating (Astrand and Rodahl 1977).

There is much evidence to support the theory that the temperature regulating center lies in the hypothalamus. The anterior portion contains the "heat loss" center which responds to increases in temperature. It activates heat loss through increased blood flow to the skin and sweating by a negative feedback system (The Industrial Environment 1973).

Human beings may be considered to be tropical animals since they require an ambient temperature of 28^{0}C when nude, to remain in thermal balance at rest (Astrand and Rodahl 1977). The oxygen uptake under these conditions is about 0.20 to 0.30 liter$\cdot$min^{-1}, corresponding to an energy production of 60 to 90 Kcal$\cdot$hr^{-1} or 70 to 100 watts (Astrand and Rodahl 1977). This heat energy is a byproduct of metabolic processes which are essential for life. The heat lost in this ambient temperature of 28^{0}C is through convection, radiation and evaporation. Convection and radiation account for about 75 percent of the heat loss while evaporation accounts for only 25 percent. The total water loss through the skin amounts to a minimum of 0.5 liter per day while water loss through the lungs accounts for two-fifths of the total evaporation (Astrand and Rodahl 1977).

If the heat content of the body is to remain constant, heat production and heat gain must equal heat loss. This is represented by Equation 1 (see following page).

$$M \pm R \pm C - E = 0 \qquad \text{EQUATION 1}$$

where: M=metabolic heat production
R=radiant heat exchange (positive if the environment temperature is higher than skin temperature)
C=convection heat exchange (positive if the air temperature is higher than skin temperature and)
E=evaporative heat loss.

(The Industrial Environment 1973)

As environmental temperatures approach 30° to 33°C, sweat evaporation becomes the only effective way to maintain thermal neutrality (Baxter 1964, Murphy and Ashe 1965, Adolph 1969). This is because evaporation is the most efficient method to dissipate heat. Every gram of sweat evaporated from the body surface, dissipates 58 Cal. of heat (Guyton 1977). Thus, if a man evaporates one liter of sweat in one hour, he dissipates 580 Cal. of heat.

There are three important factors influencing evaporative cooling. These include sweat rate, environmental humidity and air movement. In relative humidity above 90 percent, only one-third of all secreted sweat is evaporated, while two-thirds run off the body and offer no cooling effect (Eichna et al. 1950). Additional clothing and lack of air movement retard evaporation by resulting in stagnant humid air surrounding the skin surface (Fox 1960).

Sweating is activated by a rise in core temperature, not skin temperature which responds to very rapid temperature changes long before the central core temperature has been af-

fected (Astrand and Rodahl 1977, Winslow and Gagge 1941, Wyndham 1967). Water for the production of sweat initially comes from the blood. The first response to heat is vasodilitation, with as much as ten liters of blood per minute (an increase of 20 percent) being diverted through peripheral vessels to facilitate cooling (Belding 1962, Astrand and Rodahl 1977). If sweating cannot be evaporated rapidly, core temperature will increase. This will in turn increase metabolic activity, thus increasing heat production and could ultimately result in heat illness (Baxter 1964). Heat illness is a direct result of excess sweat loss leading to hypovolemia, increased work load on the heart and ultimately circulatory collapse (Senay and Christensen 1968, Adolph 1969, Belding 1962, Pitts et al. 1944). Hypernatremia and hyperkalemia also result (Ladell 1949). Adolph (1969) found that a fluid loss of only one percent of body weight caused significant circulatory stress, thus demonstrating the high morbidity associated with excessive sweat loss secondary to heat stress. The three major types of heat illness in their order of severity include heat cramps, heat exhaustion and heat stroke. Inadequate heat loss, increased environmental heat and increased metabolic heat production contribute to these illnesses. The manisfestations seen with heat illness reflect salt and water deficits with heat stroke resulting from a complete breakdown of heat control by the body. (See Appendix 3 for more detailed descriptions.)

Several indices have been suggested to be used to

protect workers against heat illnesses. One index utilizes the following categories: intolerable conditions, just tolerable conditions, (tolerable for intermittent exposures only) and easily tolerable conditions. The first two conditions may be encountered in cases of emergency. The limiting factors in these intolerable conditions may be the heat pain perceived through the skin or the core temperature rise due to inadequate heat dissipation (Astrand and Rodahl 1977).

Another index utilizes the following criteria based on rectal temperatures: "easy" conditions for rectal temperatures less than 38^{o}C and "excess" conditions for rectal temperatures above 39.2^{o}C (Astrand and Rodahl 1977).

The best known and widely used estimation of heat stress is Yaglou's WBGT index (see Equation 2 on the following page). This index was prepared for the United States Marine Corps and includes the following parameters: wet bulb temperature, dry bulb temperature and black globe radiant heat temperature, all at a wind speed of 5 miles per hour. Because of its simplicity, the WBGT index has been adopted as the principal index for a tentative Threshold Limit Value (TLV) for heat stress by the American Conference of Governmental Industrial Hygienists (ACGIH) (The Industrial Environment 1973). (See Appendix 4 for recommendations.)

In sunlight: WBGT= 0.7 wet bulb temperature EQUATION 2
+ .2 black globe temperature
+ .1 dry bulb temperature

Indoors: WBGT= 0.7 wet bulb temperature
+ 0.3 black globe temperature
(See Appendix 4)

(The Industrial Environment 1973)

FACTORS ASSOCIATED WITH HEAT INTOLERANCE

There are many factors associated with heat intolerance. These include hydration status, acclimitization history to heat, age, sex, circadian rhythm, recent alcohol history, weight and training status and they will all be taken in consideration for the purposes of this study. The following paragraphs will address these factors and their relation to heat tolerance.

PHYSICAL CONDITIONING

The main factor associated with heat intolerance is physical training status. Many studies have shown greater heat tolerance after a period of conditioning. Gisolfi (1973) showed an increase of approximately 25 percent in heat tolerance after 8 weeks of training (with a 15 percent increase in VO2max). One study found that heat tolerance time of men in heat was extended by about 40 percent as measured by rectal temperatures after five weeks of physical conditioning (Myles and Chin 1979). The increased performance seen with physical conditioning is a result of physiological changes occurring within the body. There is increased pulmonary ventilation, VO2max (10 to 30 percent depending on initial fitnes), stroke volume and maximum cardiac output, total hemoglobin and blood volume, sweat rate (a sweat

loss of 3 to 6 percent of body weight in 2 hours is average), and muscle adaptation. There is decreased blood lactate levels, heart rate, and systolic blood pressure (secondary to improved peripheral circulatory regulation) (Astrand and Rodahl 1977, Andersen et al. 1971, Murphy and Ashe 1963, Victor and Chmielinsky 1982, Belding 1962, Hoppeler et al. 1985).

There is a linear relationship between work performance and VO2max since work performance depends to a great extent upon the ability to take up, transport, and deliver oxygen to the working muscle (Myles and Chin 1979). Therefore, the VO2max is considered the best laboratory measure of a person's physical fitness (assuming the definition of physical fitness is restricted to prolonged heavy work capacity) (Astrand and Rodahl 1977, Andersen et al. 1971, Hoppeler et al. 1985, Epstein et al. 1965, Victor and Chmielinski 1982). When relating VO2max to body weight, the ability to move the body can be evaluated. Studying the relation of muscle mass and blood volume to VO2max per kilogram fat-free body weight, makes it possible to analyze dimensions versus function. The VO2max increases with age up to a maximum at 20 years. Beyond this age, there is a gradual decline. Before the age of twelve, there is no significant difference between girls and boys, but after puberty the average difference in VO2max between woman and men is 25 to 30 percent (Astrand and Rodahl 1977). The gradual decline in VO2max beyond age 20 is due to a decrease in maximal heart rate and inactivity. Inactivity reduces the stroke volume and perhaps the efficiency

of the regulation of the circulation during exercise (Astrand and Rodahl 1977). Top athletes in endurance events have a $\dot{V}O2max$ that is about twice as high as the average person. The highest figures obtained so far on athletes include: 7.4 liters$\cdot$min^{-1} for a male cross-country skier, and 4.5 liters$\cdot$min^{-1} for a female cross-country skier. Looking at the relation between this value and body weight gives us a maximum recorded value of 94 ml$\cdot$kg$^{-1}\cdot$min^{-1} for a male cross-country skier and 77 ml$\cdot$kg$^{-1}\cdot$min^{-1} for a female cross-country skier. A VO2max of 80 ml$\cdot$kg$^{-1}\cdot$min^{-1} is required for Olympic medals in certain sport events (Astrand and Rodahl 1977). (See Appendix 5 for average VO2max by age.)

As mentioned, a trained individual is better able to adjust to heat than one who is untrained. The increased metabolic rate during training demands a high thermoregulatory response and thus induces an increased peripheral sensitivity of the sweat glands to the central sweating drive (Astrand and Rodahl 1977). With increases in VO2max by training, a given rate of exercise will require a lower percentage of VO2max to stimulate the central sweating drive which results in decreased core temperatures. Thus, physical training seems to increase the slope of the sweating rate-core temperature curves, i.e., the activity of the sweat glands increases at a given core temperature (Astrand and Rodahl 1977). Physical training also improves the circulatory potential and thereby, allows a trained individual to maintain a cardiac output sufficient to meet metabolic requirements and the demand for peripheral blood flow

for a longer period of time than untrained people (Astrand and Rodahl 1977). This response will probably explain any increases in heat tolerance time seen in chemical defense gear. An increase in sweat rate secondary to conditioning will have no effect due to the impermeability of the gear.

Physical training exposes the individual to a training load or work stress of sufficient intensity, duration, and frequency to produce a measurable training effect. To achieve such a training effect, it is necessary to expose the individual to a stress which is greater than the one regularly encountered during everyday life.

The intensity of the load required to produce a training effect increases as the performance is improved in the course of training. The effective training load is therefore relative to the level of fitness; the fitter a person is, the greater training load it will take to improve that fitness. Thus, an adaptation to a given load occurs over time and increased training intensity is then needed to achieve further improvement (Astrand and Rodahl 1977).

The exact training load which will produce an optimal training effect is not established in general terms. It varies from one individual to another and is dependent on age. In fitness training for average people, it appears that a training load in excess of 50 percent of their VO_2max is sufficient to produce a significant effect (Astrand and Rodahl 1977). Based on the general concepts reviewed above, the American College

of Sports Medicine has made the following recommendations for the quantity and quality of exercise to develop and maintain cardiorespiratory fitness and body composition (Astrand and Rodahl 1977). The intensity should correspond to 50 to 85 percent of VO2max as an appropriate average conditioning intensity. They recommend exercise sessions of moderate duration (50 to 60 minutes of continuous or discontinuous aerobic activity). However, duration is dependent on the intensity of the activity, thus lower intensity activity should be conducted over a longer period of time. Three to five sessions per week is also recommended. Furthermore, they recommend any activity that uses large muscle groups, that can be maintained for a prolonged period, and is rhythmical and aerobic in nature. In most cases, the training effect obtained from the preceding recommendations, allows individuals to increase the total work done per session. The most significant conditioning effects are observed in the first 6 to 8 weeks of training (American College of Sports Medicine 1975).

In addition to increased aerobic performance, highly trained individuals can also operate at a higher percentage of their VO2max for a longer period of time than untrained persons (Astrand and Rodahl 1977, Myles and Chin 1979). They also find work in heat easier than untrained individuals with a decreased incidence of symptoms such as syncope reported (Myles and Chin 1979). Similar heat tolerance improvements were seen in British soldiers in moderately humid heat (60 percent relative

humidity) (Myles and Chin 1979). This has also been demonstrated in rat studies which showed that endurance increased the ability to run in the heat and endure higher environmental temperatures that previously caused fatal outcomes (Fruth and Gisolfi 1983).

ACCLIMATIZATION

Acclimatization also plays a role in maintaining homeostasis during heat stress. Heat acclimatization refers to a series of physiological adaptations enabling increased work capacity under hot conditions. When an unacclimatized individual is first exposed to heat stress, he exhibits increased circulatory strain due to poor peripheral heat conductance and a low sweating capacity. Acclimitization begins to occur during the first four days of heat exposure, as manisfested by an increase in blood flow from the internal core to the peripheral regions. This results in heat conductance of five to six times its baseline value. There is also an increase in sweat rate and a sodium loss greater than 50 percent (Frisancho 1981).

Unacclimatized workers in heat exhibit increased heart rate and core temperature, decreased stroke volume, unstable blood pressure, flushed skin and a dull apathetic attitude. As acclimatization occurs, the heart rate, skin and core temperature, aldosterone secretion, and electrolyte concentration decreases; blood volume, stroke volume, and sweat rate increases (up to 100 percent) (Astrand and Rodahl 1977)); and circulatory

stability takes place (Piwonka and Robinson 1967, Frisancho 1981, Guyton 1977, Bean and Eichna 1943).

Acclimatization also positively affects work performance (Bass et al. 1955, Houston and Riley 1947). Several military exercises have demonstrated this increase in work performance by both natural and artificial acclimatization. One study showed that the heat acclimatized groups suffered less heat stress, performed better and had fewer casualties than did the control groups (Myles and Chin 1979). Another study exposed two groups to a period of physical training in either hot or cool environments. The improvement in work heat tolerance in the acclimatized group was significant (Myles and Chin 1979). Another study showed that acclimatization made a difference on work performance on two groups of already physically fit men. Approximately 90 percent of the heat casualties occurred in the unacclimatized group (Myles and Chin 1979). They suffered more dehydration and had lower sweat rates, higher body temperatures and higher heart rates after exercise (Myles and Chin 1979). Another Air Force study reported similar findings after testing both acclimatized and unacclimatized physically fit individuals (Myles and Chin 1979). Thus, the above studies demonstrate that a well-trained individual adjusts better to heat than one who is in poor condition, but training alone cannot replace acclimatization (Astrand and Rodahl 1977).

Acclimatization can be best produced by several consecutive days of work in heat (Belding 1962, Frisancho 1981, Lind

and Bass 1963). Within 4 to 7 days of heat exposure, most of the physiological changes permitting greater heat tolerance have taken place, and at the end of 12 to 14 days the acclimatization is complete (Astrand and Rodahl 1977). The effect of heat acclimatization persists several weeks following heat exposure, although some impairment in heat tolerance may result in a few days following cessation of exposure, especially if the individual is fatigued and alcohol has been consumed (Astrand and Rodahl 1977).

HYDRATION STATUS

Water loss from the gastrointestinal tract, respiratory tract, skin and kidneys occur daily. This loss is balanced by water intake from fluids and food, and water liberated during the oxidation in the cells (Astrand and Rodahl 1977). This loss can be considerably increased when the individual exercises or is exposed to hot environments and thus, disturbs his delicate homeostatic balance.

In adults about 70 percent of the lean body weight is water, thus serving as a buffer system to cover water losses over limited periods of time. Any change in the internal environment leading to cellular dehydration will elicit the thirst response. A water deficit will also stimulate antidiuretic hormone secretion, causing an increased reabsorption of water and thus reduced urine formation (Astrand and Rodahl 1977).

The salt concentration of sweat is less than that

of blood, and sweat loss therefore causes an increase in the salt concentration of the blood leading to thirst and reduced urine formation, as mentioned previously. Voluntary water intake does not necessarily cover the water loss induced by excessive sweating (Astrand and Rodahl 1977). This dehydration risk is greatest in individuals unaccustomed to heat.

Physiologically, the regulation of body temperature takes precedence over the regulation of body water (Astrand and Rodahl 1977). If dehydration is allowed to progress, it could be a threat to life in hot environments with no available water. Dehydration results from excessive sweat loss due to work in high environmental temperatures that require evaporation for heat dissipation. The only source of fluid for evaporation is from the inner body and the only rapid outlet is through the sweat glands.

Exercise raises core temperature so that profuse sweating is possible to enable heat dissipation through evaporation. It is also able to stimulate sweating seconds after the onset of work, before core temperature even increases, by some unknown mechanism (Astrand and Rodahl 1977). Belding (1962) showed that a man can produce 3 liters of sweat for brief periods with a sweat rate of up to 1.5 liters/hour in 24 hours. Winslow and Gagge (1941) found that men riding bicycle ergometers for 90 minutes in hot conditions increased their sweat production 3 to 5 times for each 2 to 3 fold rise in metabolism. Adolph (1969), in a series of desert studies, found that for each per-

cent loss of body weight due to sweating, rectal temperatures rose .55 F. He also showed that only 1 percent loss of body weight due to sweating increased circulatory strain. Eichna et al. (1950) showed that sweat rates were not decreased by moderate dehydration, while Adolph (1969) found that subjects dehydrated to 6 percent of body weight decreased their sweat rates.

Work performance is influenced by a water deficit, even if the loss is only about 1 percent of the body weight as demonstrated by several studies cited in Astrand and Rodahl 1977. At submaximal work loads, the heart rate and body temperature are higher than normal, while the stroke volume is reduced (Astrand and Rodahl 1977). Well-trained subjects are less affected by dehydration in their work performance than untrained subjects (Astrand and Rodahl 1977). Acclimatization to heat does not seem to protect from deteriorating effects of dehydration (Ellis et al. 1954).

Many studies have shown the beneficial effects of fluid replacement. Plain water is recommended to maintain a low heart rate and produce the greatest sweat rate. This is because fluid losses from sweating are much greater than electrolyte losses. Drinks such as Gatorade (Tr) are not recommended, as the added glucose slows gastric emptying which delays absorption of water from the small bowel (Exertional Heat Injury 1985).

SEX

Women have a higher tissue conductance of heat and a higher peripheral reaction to climatic stress. This, however, appears to have no importance for the performance of work (Astrand and Rodahl 1977).

AGE

Age reduces heat tolerance. VO2max, an index of fitness, declines 20-30 percent between ages 30 to 65. Under levels of high heat stress, the older person compensates for heat loads less effectively than his younger counterpart, as indicated by higher core temperatures and lower maximal capacity for the same work output (The Industrial Environment 1973). The older person also starts to sweat later and takes longer to return to normal body temperatures after heat exposure than his younger counterpart. One study found that 70 percent of all individuals who suffered heat stroke were over sixty years of age (Astrand and Rodahl 1977).

WEIGHT

In obese individuals, body surface area (BSA) to body weight (BW) ratio is relatively low. Because heat loss is a function of BSA, (necessary for radiation and convection) and heat production a function of BW, a low BSA/BW ratio is a threat to sustained work performance in heat (The Industrial Environment 1973, Frisancho 1981).

ALCOHOL

Recent excessive alcohol intake (hours to several days) prior to heat stroke development has been widely documented. It has also been noted that workers have reduced heat tolerance on the day following an alcoholic "binge". Since alcohol suppresses antidiuretic hormone, dehydration secondary to water loss in urine may be a factor (The Industrial Environment 1973).

CIRCADIAN RHYTHM

A variety of physiological functions, including heart rate, oxygen uptake, rectal temperature, and urinary excretion of potassium and catecholamines, show distinct rhythm changes in a course of a 24 hour period. The values fall to their lowest point during the night (low dip around 4 A.M.) and rise during the day, reaching their peak in the afternoon. This phenomenon is known as circadian rhythm and is regulated by biological clocks. These 24 hour changes are also associated with changes in performance and highly correlated with rectal temperature changes. Thus circadian rhythms must be considered in physiological experiments and performance tests performed at different times of the day (Astrand and Rodahl 1977).

EXERCISE TESTING

Proper exercise testing measures oxygen consumption or the performance of a measured amount of work by the subject. The exercise level must be easily performed by the subject and

the rate of work performed set at any desirable level. The exercise should activate large muscle groups and should not require special skills or co-ordination. A difficult and unfamiliar task may create anxiety and may lead to a discontinuous and uneven work rate with a bias in the physiological results. A learning effect might also be seen as familiarity with the exercise would enable the subject to perform more efficiently. General laboratory environment and exercise tasks should be hazard free to decrease anxiety and eliminate injury (Andersen et al. 1971).

There are several types of ergometers suitable for routine exercise testing. The most popular are bicycle ergometers (upright or supine), steps, treadmills, and arm cranks (see Appendix 6 for advantages and disadvantages of each). They can all be used to measure VO2max after exposure to strenuous and exhaustive exercise. VO2max can be measured directly by performing muscular exercise at increasing intensities and establishing the level of work rate above which a further increase in work output does not bring about an increase in oxygen uptake. The "plateauing" of oxygen uptake is the single best criterion that the maximum value (VO2max) has been reached (Andersen et al. 1971).

Many physiologists prefer the bicycle ergometer for routine tests or studies of physical work capacity (Astrand and Rodahl 1977). The technique involved is simple and the energy output or the oxygen uptake can be predicted with greater

accuracy than for other types of exercise. The mechanical efficiency is independent of body weight, thus the work load can be selected according to the subject's gross body weight and effort is known more precisely than in other types of effort (Andersen et al. 1971). The bicycle ergometer operated with a mechanical brake is inexpensive, is easy to move from place to place and is not dependent on electricity for use. Since the subject exercises sitting or lying with arms and chest relatively immobile, it is simple to obtain good EKG tracings and to perform studies with indwelling catheters, blood sampling, rebreathing procedures, blood pressure measurements, etc. The type of bicycle ergometer which produces a constant load regardless of pedal frequency has the disadvantage that during maximal work a tired subject is unable to maintain the tempo and may be forced to discontinue work before it is possible to complete a critical measurement. With use of a bicycle ergometer in which the work load varies with the pedal frequency, the load drops when the tempo no longer can be maintained, but the subject is able to continue. A pedaling rate of 50 to 60 revolutions per minute (rpm) should be used in all tests since this is the most comfortable rate for people of average fitness. The rate should be kept constant with a metronome or tachometer and the subject should be kept seated.

As stated previously, there are two types of bicycle ergometers, mechanical and electrical, which can be used in supine or upright positions. Mechanical friction force is devel-

oped on or within the bicycle wheel and the work performed is proportional to the product of the applied force and the total number of wheel revolutions as indicated by the following equation.

Total work output = W(t)=W X A (kpm/min) EGUATION 3.
where:

<u>W</u>=work (indicated by kilocalories per minute (kpm) on the machine) performed during one rotation of the ergometer wheel
<u>A</u>=number of rotations of the wheel in time (t) which is indicated by a revolution counter
<u>W(t)</u>=total work performed

(Andersen et al. 1971).

The source of friction is normally a weighted leather belt applied to the outer surface of the driving wheel. The bicycle is constructed to allow the work rate to be recorded and to also permit changes in the work rate while the pedaling rate is kept constant. This method of exercise testing often causes a subject to experience a feeling of local fatigue or pain in the thighs, buttocks or knees. This discomfort may cause the work effort to be interrupted before the VO2max is reached. The work position is of critical importance. The subject should be sitting vertically over the pedals with the seat high enough so that the leg is almost completely stretched when the pedal is in its lowest position (Astrand and Rodahl 1977). VO2max obtained in the supine position are lower than those attained in the upright position, thereby requiring notation of the position used during testing (Andersen et al. 1971).

Use of the bicycle ergometer includes exposing the subject to one or two submaximal loads with the load adjusted

so that the heart rate is at least 140 beats·min^{-1} for subjects less than 50 years of age, and 120 beats·min^{-1} for subjects more than 50 years of age. Then a "supermaximal" load should be tried. If this load is tolerated for at least 2 minutes, measurements carried out at the end of the work period are likely to give an oxygen uptake equal to or close the the individual's VO2max. Usually this "supermaximal" load is selected on the basis of the individual's predicted VO2max using the nomogram of Astrand (Astrand and Rodahl 1977) (see Appendix 7). A load is then selected which corresponds to a 10 to 20 percent increase over predicted VO2max values (see Appendix 7). If the subject at the end of the minute on the selected load has difficulty in keeping up the pedaling rate and starts to hyperventilate the load is lowered slightly. If the subject appears to have more strength left than predicted the load is slightly increased. Table 1 contains the predicted VO2max as a function of work load.

Table 1. WORK LOAD AND VO2MAX

Bicycle Ergometer		
Work Load		Oxygen uptake
watts	kpm·min^{-1}	liters·min^{-1}
50	300	0.9
100	600	1.5
150	900	2.1
200	1200	2.8
250	1500	3.5
300	1800	4.2
350	2100	5.0
400	2400	5.7

(Astrand and Rodahl 1977)

Heat exposure represents an extra load on the blood circulation, and exhaustion occurs much sooner during heavy

physical work in heat because the blood has to carry heat from the interior of the body to the skin. However, one study found no difference in VO2max in subjects working in heat and at comfortable temperatures (Astrand and Rodahl 1977). At submaximal work loads, they did find increased heart rate and decreased stroke volume in heat (Astrand and Rodahl 1977). At the same work load, the temperature difference between the core and the skin is 4.9^{0}C in cool environments, but only 0.9^{0}C in the heat, thus necessitating a greater skin blood flow in the heat and thus an increased heart rate (Astrand and Rodahl 1977).

The classical method for the determination of oxygen uptake is the Douglas bag method. It is sound and well tested under a wide variety of circumstances. It is relatively easy and unsurpassed in accuracy (Astrand and Rodahl 1977). Its major disadvantage is that the subject is somewhat hampered by the equipment required for the collection of expired air. Furthermore, it only provides a mean figure for the oxygen uptake in any given time in which expired air is collected. On a bicycle ergometer the objective is to be able to collect two Douglas bags of expiratory air requiring a collection time of no less than 1 minute for analysis.

The Douglas bag method to collect expired air samples consists of a mouthpiece, noseclip, series of tubes, stopcock and bag. The inner area of the mouthpiece is 400 mm , the inner diameters of the tubes in the valve, stopcock, and bag are 28 mm, and the connecting tube (smooth), 35 mm. The tubes should

be as short as possible. The respiratory rate is registered via a Marey capsule. Two Douglas bags are connected to the four-way stopcock for continuous collection of air with the subject connected to the bag during inspiration. The turning of the stopcock starts the stopwatch, which can be read down to .01 minutes. When 50 liters or greater of expired air have been collected, the stopcock is turned to the second bag or to room air. The stopcock is always turned during inspiration. The second turning of stopcock automatically stops the stopwatch. The volume of expired air is measured in a balanced spirometer and the composition of the air is analyzed by the Haldane or Micro-Scholander or by electronic gas analyzers. When using electronic gas analysers, correction for water pressure in the expired gas in relation to the gas used for calibration must be performed to eliminate error.

Work test procedures may vary from a single-level load to an intermittent series of increasing loads with rest periods of varying lengths. These procedures may also consist of almost continuous increases in load, or continuous series of increasing loads with steady states at each level (only possible for loads below 50 to 70 percent of VO2max). With single level loads, the heart rate should be above 200 beats$\cdot$min^{-1} and the work period about 6 minutes. For multiple-level tests, work periods at each load should exceed 5 minutes. If the oxygen uptake is to be measured and if steady-state values are to be obtained, the noseclip, mouthpiece, and respiratory valve are

placed on the subject 4 minutes after the beginning of the test load and the collection of the expired air is performed 5 minute after the start of the test.

Maximal exercise tests deal with intensities that may produce fatigue or symptoms that will prohibit further testing. They also achieve VO2max and no further increases in heart rate. A submaximal exercise test takes the subject to a predetermined endpoint such as 85 percent of predicted VO2max, a certain exercise intensity, or a predetermined heart rate. Submaximal testing may be useful for determination of fitness where a diagnostic test is not required but the VO2max obtained from this data is often unreliable. This testing may have some value for predicting coronary disease risk in an asymptomatic person. Submaximal testing may be useful in monitoring changes in fitness resulting from an exercise program though the comparison of heart rates obtained during submaximal exercise, but again the results may be unreliable as heart rate may be influenced by other factors, i.e., drugs, temperature, etc.

Table 2 lists several contraindications for exercise testing (see following page).

Table 2. CONTRAINDICATIONS TO EXERCISE TESTING

1. Recent acute myocardial infarction
2. Unstable angina
3. Neuromuscular, musculoskeletal, or rheumatoid disorders
4. Excess anxiety
5. Manifest cardiac failure, symptoms and electrocardiographic signs of impending or acute myocardial infarction and myocarditis and aortic stenosis
6. Acute infectious diseases, unstable metabolic conditions and probability of recent pulmonary embolism
7. Suspected or known dissecting aneurysm
8. Significant emotional distress (psychosis)
9. Acute pericarditis
10. A recent significant change in the resting EKG
11. Resting diastolic blood pressure over 120 mm Hg or resting systolic blood pressure over 200 mm Hg
12. Electrolyte abnormalities
13. Any serious systemic disorder (mononucleosis, hepatitis, etc.)
14. Thrombophlebitis or intracardiac thrombi

(American College of Sports Medicine 1975, Andersen et al. 1971)

Prior to exercise testing, a thorough medical history should be recorded. A complete physical exam should be performed by a physician. This should include a thorough evaluation of the cardiorespiratory system using a multi-lead EKC recording. An informed consent should be obtained with all questions answered. The testing team should include a qualified physician (preferably a cardiologist) and 2 technicians. During exercise testing, astute observations should be made regarding core temperature status and EKG recordings. Indications for stopping exercise are included in Table 3 (see following page).

Table 3. INDICATIONS TO DISCONTINUE EXERCISE TESTING

1. Chest pain
2. Sever dyspnes
3. Severe fatigue
4. Faintness
5. Claudication
6. Signs of impending emergency situations, i.e., pallor, cyanosis, confusion, moist skin, staggering, head nodding
7. Paroxysmal, supraventricular and ventricular arrhythymias
8. Ventricular premature beats appearing before the end of the T-wave, conduction disturbances other than a slight atrioventricular block
9. ST depression of horizontal or descending types greater than 0.2 mV
10. Heart rates that exceed:

Ages	Upper limits
20-29	170
30-39	160
40-49	150
50-59	140
60+	130

(Andersen et al. 1971)

Acute cardiac failure is a rare complications observed in severely ill patients with chronic valvular heart disease but sometimes occurs in healthy subjects (Andersen et al. 1971). The frequency of both minor and major complications, including arrhythmias, however, is greater during the recovery period than during the exercise itself. Postural hypotension may develop immediately after, and can provoke arrhythmias. Rapid cooling of the body may further increase the heart's susceptibility to arrhythmias and therefore, gradual tapering off of the exercise is recommended. Neither cold nor hot showers should be allowed immediately after the exercise session. Continuous EKG recording for at least 6 minutes after termination of exercising is also recommended (Andersen et al. 1971). Emergency equipment and drugs, such as a defibrillator, airway device

and glucose/saline infusion sets, should be readily available with trained personnel who know how to use them.

HEAT BALANCE ASSESSMENT

Measurements of the deep body temperature (core temperature) may be performed by use of mercury thermometers, thermocouples, or thermistors. The classical site of measurement is the rectum. Since the temperature in the rectum varies with the distance from the anus, the recommended depth is 5 to 8 cm. This rectal temperature is slightly higher than the arterial blood temperature, the same as liver temperature, and slightly lower (0.2° to $0.5^{\circ}C$) than the part of the brain where the thermal regulatory center is located. During heat exposure or physical exertion, the temperature of this part of the brain increases more rapidly than does the rectal temperature, taking 30 minutes to establish equilibrium. The temperature increase or decrease in the brain and in the rectum is of the same magnitude, however, and thus a rectal temperature is a representative indicator for the purpose of assessing changes in the deep body temperature (after steady state conditions are provided) (Astrand and Rodahl 1977).

SUMMARY

In summary, chemical warfare continues to be a threat. Its best defense is chemical defense gear which often leads to hyperthermia. Physically fit, well hydrated and acclima-

tized individuals have an increased tolerance for heat and thus these factors may have important implications for increased heat tolerance in chemical protective gear. No recent reports or studies were found to test this hypothesis. This proposal will only deal with physical fitness as the subjects will be well hydrated and controlled for acclimitization.

HYPOTHESIS

The research proposal described is based on the following assumptions:

1. Every physiologic process in the human body is designed to restore homeostasis.
2. The human body operates within a narrow range of core temperature and extremes in heat lead to hyperthermia and heat illness.
3. Increased age, weight, alcohol intake, and dehydration negatively influence heat tolerance.
4. Heat tolerance follows a definite circadian rhythm pattern similar to core temperature changes.
5. Physical fitness and heat acclimitization positively influence heat tolerance.
6. VO2max is the best measure of physical fitness.
7. A rectal temperature is an accurate measure of core temperature.
8. Chemical warfare continues to be a threat.
9. The best defense is chemical defense gear.
10. Chemical defense gear is impermeable to the evaporation of sweat, thus leading to hyperthermia in conditions of heat.

Heat tolerance time (HTT) (see definition) will be measured in chemical defense gear for both the experimental and control groups. The experimental group will then be subjected to twelve weeks of physical conditioning. Heat tolerance time will then again be measured for both groups.

Ho: Fitness does not effect HTT ($\mu d = 0$)

Ha: Fitness increases HTT ($\mu d > 0$)

A p value of less than .05 will be used to reject the hypothesis.

METHODS AND MATERIALS

RESEARCH DESIGN

This cohort study will be an experimental clinical before and after trial with controls. It will be conducted through the United States Air Force School of Aerospace Medicine, Stress Physiology Lab, located at Brooks Air Force Base, Texas. The School of Aerospace Medicine has consultant services in physiology, biochemistry, aerospace medicine, and statistics. The stress physiology lab has the exercise testing equipment, chemical defense gear, physiological testing equipment, emergency equipment and drugs, and equipment necessary to perform VO2max measurements. A physician specializing in cardiology from Wilford Hall Medical Center (WHMC), Texas will be assigned to the study for its duration.

The first step will be to submit the proposal for review to the stress physiology lab at the School of Aerospace Medicine. Then Wilford Hall Medical Center's hospital commander will receive a detailed explanation of the experiment and its benefits plus a request for the services of a cardiologist for the study (see Appendix 8). Once permission is granted for release of the cardiologist, the following steps will be initiated. Authorization to do the experiment will be first granted by the Chief of Aerospace Medicine (SGP) directly supervising

the principle investigator. The research proposal will then be distributed to the Human Use Committee for review following Air Force Regulation (AFR) 169-6 that specifies guidelines for research and use of human subjects. The proposal will have to assure the committee that confidentiality will be maintained and that the subjects have given informed consent. All information on the subjects will be handled in a coded form, assigning numbers to the last four digits of their social security numbers upon their entry in the study. Only the researcher will have access to this list of assigned numbers and social security numbers to protect the subject's confidentiality. A standard consent form adapted to this experiment's specific concerns will be handed out (see Appendix 9). It will include the risks and benefits of exercise, exercise testing, physiological monitoring, chemical defense gear wear, heat tolerance testing with chemical defense gear, and oxygen uptake measurements. Assurances will be given that any information obtained in this study will not be used against them in any way and that they may drop out at any time without prejudice. Once this is done, the proposal will then be submitted for final approval by the Systems Command Headquarters and Air Training Command (ATC) Headquarters.

Basic military trainee graduates attending technical training schools through the 3280th Technical Training Wing at Lackland AFB, Texas, will be the study population. They will have just completed a training program consisting of 1021

hours (6 weeks) with 29.5 hours for physical conditioning, 38 hours for drill training, and the rest for assorted classes, training and activities of daily living. The trainees will have eaten, slept, trained, and exercised together for the entire training and marched everywhere within walking distance. At any given time, there will be 7000 to 8200 trainees with 19 percent of them women. This is a relatively homogeneous population of high school graduates, with a mean age of 20 years. They have all passed medical qualifications, including weight restrictions (see Appendix 10 for current weight standards). They come from different parts of the United States and have differing levels of heat acclimitization prior to basic training. After one month of exercising, drill training and marching in the summer, most will become acclimitized if the temperature is sufficiently high.

Fourteen to fifteen percent of these trainees (approximately 1100 to 1200) enter the 3280th Technical Training Wing (TTW) to attend such schools as the police academy, small arms training and crypto-training. Like the basic trainees, 19 percent of this group are women. This group of new recruits in the 3280th TTW will serve as the sample population which will be appropriate as these men and women represent the large majority of the USAF personnel who will be wearing chemical defense gear in times of national conflict. The population size needed (set by the researcher) is 150. This is a large enough number to yield important results but will have to have a power analysis

after completion of the experiment to determine how good the data is, since no past studies in this topic have been done.

Detailed explanatory letters (see Appendix 8) describing the experiment and its benefit to the USAF will be first given to the drill sergeants and officers-in-charge (OIC) of the various flights that make up basic training. Enlisting the aid and support of these leaders will aid in getting recruits for the study since the trainees seek guidance from these leaders during this stressful time. This same explanatory letter will be passed out to all basic trainees graduating in a one month period that will be attending schools through the 3280th Technical Training Wing at Lackland AFB, Texas. This information will be obtained from the Manpower Personnel Center (MPC) at Randolph AFB, Texas. These graduates will be offered a base-of-preference (BOP) for their participation in the study but no other form of incentive will be introduced. Participation will be strictly voluntary and dropouts will have no punitive action taken against them. Volunteers will initially sign an informed consent and all questions will be answered (see Appendix 9).

The subjects will then be subjected to a strict medical examination by the participating cardiologist (see Appendix 11 for medical referral form) to see if they have any conditions making participation in the study inadvisable (see Table 2).

Physical fitness will then be determined, in the presence of the cardiologist and 2 technicians, by the VO2max generated

while being stressed on a bicycle ergometer. This will be performed in a sitting position with continuous EKG monitoring. The height of the saddle and handle bar will be adjusted for each subject. The knees will be flexed at approximately 5 degrees when the foot is at its lowest point. The subject will be instructed not to grip the handlebars tightly. The pedal speed will be constant throughout at 60 rpm with the aid of a metronome (60 rpm was found to produce a higher V02max than 50 rpm (Astrand and Rodahl 1977)).

The test will begin by having the subject pedal with the lowest resistance possible on the bike for a 2 minute warm-up. Then the load will be adjusted so that the heart rate is at least 140 beats$\cdot$min^{-1}(see Appendix 6). A "supermaximal" load will then be tried. (See Table 3 for indications which will be used to discontinue testing.) The "supermaximal" load will be selected using the nomogram of Astrand (Astrand and Rodahl 1977) on the basis of the individual's predicted maximal oxygen uptake from his or her heart rate at the submaximal work loads (see Appendix 6). If the subject can tolerate this "supermaximal" load for at least 2 minutes even with considerable difficulty, measurements will be carried out at the end of the work period to give an oxygen uptake equal to or close to the individual's V02max (Astrand and Rodahl 1977). A load will then be selected which will require an oxygen uptake of about 10 to 20 percent higher than the predicted maximal oxygen uptake. If the subject at the end of the first minute on the selected load has difficulty

keeping up the pedaling rate and starts to hyperventilate markedly, the load will be lowered slightly so as to allow the subject to continue for a total of about 3 minutes. If, on the other hand, the subject appears to have more strength left, the load will be increased.

Collections of expired air lasting more than a minute, will be taken in Douglas bags for gas analysis to determine oxygen uptake. This analysis measures oxygen and carbon dioxide content in the expired air volume over the sampled time. When a "plateauing" of oxygen uptake with further increases in work output occurs, the test will stop and the final oxygen uptake will be recorded as the VO2max. The time of day that the test is performed will be recorded and all subsequent tests (VO2max determination and heat tolerance time) will be performed at the same time to negate any circadian rhythm effects (see literature review).

Any VO2max that exceeds 60 $ml \cdot kg^{-1} min^{-1}$ for men and 50 $ml \cdot kg^{-1} min^{-1}$ for women, will eliminate that subject from the study. This is based on the premise that already fit subjects will require several hours per day of training to produce an effect on their performance because of their high load adaptation (Astrand and Rodahl 1977). These figures were chosen by the researcher, based on averaging Hossack and Bruce's (1982) VO2max chart of sedentary men and women by decade (see Appendix 5) and the required VO2max for the achievement of certain Olympic medals (see literature review).

After a necessary sample size of 150 is generated, the sample will be randomly divided into 2 groups, control and experimental, using a random number table (see Appendix 12). The coded number given to each subject will be used. A starting place of row 27 and column 2 has been arbitrarily chosen to start the selection with the first number assigned to the experimental group and every other one thereafter. The remainder, will be put in the control group. By randomly assigning each subject to one of the 2 groups, bias from confounders such as sex, height, weight, diet, drug intake, alcohol intake, smoking, physical fitness, age, and acclimitization to heat, will be matched and thus reduce any bias they may have on heat tolerance.

Heat tolerance time will then be the final value assessed. Again in the presence of the cardiologist and 2 technicians, each subject will be stress tested in chemical defense gear. This will be carried out on the same bicycle ergometer at the same time of the day as their VO2max test. This will involve submaximal testing, however. One of three protocols will be selected according to the subject's weight and activity status (see Table 4). Activity status will be subjectively determined by the test administrator from verbal query. Individuals who have been regularly participating (the last 3 months) in vigorous activities for at least 15 minutes, 3 times per week, will be classified as very active. Continuous EKG and five minute rectal temperature monitoring will be performed.

Water will be offered every five minutes which can be taken through a special adaptation on the gas mask. A rectal temperature of 39°C will be the endpoint of the stress testing and the total time tested will be recorded.

Table 4. PROTOCAL FOR SUBMAXIMAL EXERCISE TESTING

Test Protocol

	Test Stages (minutes)			
Protocol	I (1-2)	II (3-4)	III (5-6)	IV (7-8)
A	*25 (150)	50 (300)	75 (450)	100 (600)
B	25 (150)	50 (300)	100 (600)	150 (900)
C	50 (300)	100 (600)	150 (900)	200 (1200)

*workload in watts (kilogram meters per minute)

Protocol Selection Criteria

Body weight in kg (lbs)	Very Active? No	Yes
<73 (160)	A	A
74-90 (161-199)	A	B
>90 (200)	B	C

(American College of Sports Medicine 1975)

After the medical history, heat tolerance time and VO2max have been generated, the experimental group will begin its training. A twelve week training session has been chosen, which exceeds previous studies, to add an extra degree of certainty that the subjects will display a training effect. This same rationale is behind the decision to exercise subjects daily in spite of the recommended 3 to 5 times per week. They will each exercise at 85 percent of their VO2max (determined individually for each subject) for 60 minutes per day to produce an increased level of fitness. This duration and intensity will be monitored by the 2 technicians and the cardiologist. A metronome will be used to keep a rhythm corresponding to 60 rpm. Training will take place indoors in a mean temperature

of 18^{0} to 21^{0}C to negate any confounding acclimitization effects. Alcohol and smoking will be discouraged for both groups and absolutely forbidden 12 hours prior to any testing. A blood alcohol level will be drawn prior to each test to make sure the subject is alcohol-free. Drugs, except those permitted by the cardiologist, will be forbidden. Subjects will be told that random urine testing may occur any time per the current policy of the USAF. All meals will be taken at a common mess hall and eight hours of sleep will be encouraged. Each subject will still attend his/her technical training classes but the experimental group will exercise an hour at Brooks AFB, Texas (with half the group conditioning before classes and the other half after). Transportation will be provided for each subject to and from Brooks AFB, as this distance is approximately 18 miles from Lackland AFB.

After the 12 weeks of training are completed, all subjects will again have their VO2max and heat tolerance time tested. This will be carried out at the same time of the day as previous tests and in the same manner.

DATA COLLECTION

AND STATISTICAL ANALYSIS

The study subjects will be described according to age, height (Ht), and weight (Wt1). This information will be taken from their initial medical examination. Heat tolerance time (T1) and VO2max (VO2max1) will also be recorded and tabulated according to each subject's coded number. At the end of the experiment, heat tolerance time (T2), VO2max (VO2max2) and weight (Wt2) will again be recorded and tabulated along with the change in heat tolerance time (T2-T1), VO2max (VO2max2-VO2max1) and weight (Wt2-Wt1) (see Table 5).

Table 5. EXPERIMENT RESULTS

EXAMPLE:

Subj #	Age	Ht	Wt	VO2max1	T1
1					
2					
3					
4					
5					

Subj #	T2	VO2max2	Wt2
1			
2			
3			
4			
5			

Subj #	T2-T1	VO2max2-VO2max1	Wt2-Wt1
1			
2			
3			
4			
5			

Research technicians will generate and record the above data. These data are in a usable form to facilitate automated computer entry for software packages dealing with matched t-tests, power analysis and linear regression analysis. A matched t-test will be used since continuous data will be generated and two study groups, i.e., before and after, will be compared. A sample mean, standard deviation and standard error of the mean will be computed. A 95 percent confidence level will be used for each sample and a statistical difference will exist if a 95 percent confidence limit for one sample fails to overlap the average of the other sample. The before and after results of the untrained group should show no statistically significant difference and if a difference is shown, then some other factor is responsible for the increased heat tolerance time of the trained group (Riegelman 1981).

Power analyses would be employed to judge the adequacy of sample size. Power is the probability of rejecting the null hypothesis when the alternate hypothesis is true. Several factors can influence this value. Power increases if the sample size (n) increases, if the true value of the differences between the means (μd) increases away from zero, if the standard deviation of the differences (σ) were to become smaller, or if an alpha error (α) (rejecting the null hypothesis when it is true) were increased. In order to compute power as a function of the mean of the differences, we can estimate the standard deviation of the differences by Sd (the actual standard deviation

found in our sample). In order to compute the sample size necessary at a certain power, one must first specify the alpha value desired, the true mean of the differences (estimated by the mean of the sample differences found in the study), the standard deviation of the differences (estimated by Sd as mentioned previously), and the power or probability with which one wishes to detect this difference. Using the different power values, a comparison of the mean of the differences can be calculated by using a power table (see Table 6) (Eifler 1985).

Table 6. POWER TABLE
Power of test Ho:ud_____0 for n=___, d=___, =___.
(one or two sided)

ud=					
power=	.50	.80	.90	.95	.99

(Eifler 1985)

It is usually only possible to provide a rough estimate of the standard deviation of the differences. For this reason the sample size computed should be considered a lower bound and therefore, should be increased.

Multiple linear regression techniques will also be employed to study the relationship between VO2max (as an indicator of physical fitness), the independent variable, and heat tolerance time, the dependent variable, thus enabling a dose effect to be shown. A plotted scattergram of the VO2max1 to T1, VO2max2 to T2, and VO2max2-VO2max1 to T2-T1 will be used to help to measure the strength of association, statistical

significance and the extent of variation in the level of physical fitness and heat tolerance time that can be explained by physical conditioning. A straight line representing the best line that can be drawn through the data may be seen if a linear association exists. If a line can be drawn, it is possible to derive a summary expression of the relationship between physical conditioning and heat tolerance time by calculating the slope of the best line. The change in weight will also employ regression techniques to determine how much effect it has on the dependent variable, heat tolerance time (Kuzma 1984, Riegelman 1981).

TIME AND FACILITIES REQUIRED
(Including Action/Personnel/Materials Required)

Dec 86 to Mar 87:	Submission of proposal to Chief of Aerospace Medicine (SGP). Obtain permission from SAM stress physiology lab for equipment (bicycle ergometer, gas analyzer, emergency crash cart and drugs), personnel, chemical gear and lab use. Obtain permission from WHMC's commander for use of cardiologist. Submit proposal to Human Use Committee with consent form. Alter proposal as suggested by above.
Apr to May 87:	Final study plan completed, incorporating suggestions made. Obtain permission from Systems Command and ATC Headquarters. Work with MPC regarding basic trainee attendance of technical training schools at Lackland AFB, Texas. Print up consent forms, explanatory letters, medical examination sheets, and tables for data. Secure use of software package for statistical analysis. Request help from statistician from SAM. Train 5 research assistants from SAM for study (they are already trained for exercise testing). Provide cardiologist with necessary information to conduct and complete the study. Work with MPC regarding BOP for subjects. Obtain 150 Douglas bags, 150 disposal rectal probes, 150 sets of disposal EKG disks and 30 tubes of EKG paste.
Jun 87:	Researcher to submit detailed letters to drill sergeants and OIC. Detailed letters also sent to potential volunteers (all trainees attending 3280th Technical Training Wing at Lackland AFB). Informed consent given and consent forms signed. Confidentiality assured. Medical examinations done by cardiologist.

1-3 Jul 87:	VO2max generated. Generate the necessary sample size. Determine 85 percent of VO2max. Tabulate results.
6-9 Jul 87:	Heat tolerance time generated and recorded. Tabulate results.
13 Jul to 5 Oct:	12 weeks of physical conditioning.
6 Oct to 13 Oct:	Obtain weight, VO2max, and heat tolerance time.
13 Oct to 10 Feb:	Tabulate data. Statistician to do statistical analysis utilizing computer. Requires secretary, office space, data processor, computer supplies, office suppliea, typewriter. Prepare report for publication. Submit report to interested commands, SGP, SAM and WHMC's commander.

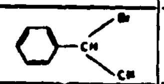
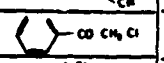
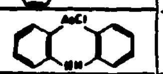
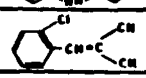
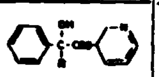
CONCLUSIONS

A conclusive demonstration that physical conditioning increases heat tolerance while a subject is tested in chemical defense gear would be a justification for the USAF to develop a mandatory physical training programs for each USAF member. This would justify allocation of funds to establish and maintain such programs. Actual use of chemical warfare gear by physically fit airmen, would enable the airmen to either work more efficiently or longer in conditions of thermal stress. Completion of each airmen's duty could mean the difference between completion of the mission and insuring preservation of national security, or compromising that security by failure to attain mission goals.

APPENDIX 1

Principal Agents of Chemical Warfare

by courtesy of SCIENCE JOURNAL London

	US Army Code	Trivial Name	Chemical Structure	Normal Physical State	Smell	Disseminated Form	Symptoms of Intoxication	Time of Onset of Symptoms	LD_{50} * Percutaneous Absorption (mg per man)	LCt_{50} * Inhalation (mg-min/m³)	LCt_{50} * Percutaneous Absorption (mg-min/m³)	Incapacitating Dosage (mg-min/m³)	First Use or Country of First Development	Remarks
LETHAL AGENTS	CG	phosgene	$Cl_2C=O$	colourless gas	new-mown hay, imparts metallic taste to tobacco smoke	gas	lethal coughing, retching, frothing at mouth, cyanosis, asphyxia, pneumonia	generally delayed for several hrs		3200			Germans 1915	produced 80% of WW1 gas fatalities, extensively stockpiled in WW2
	AC	prussic acid	HCN	colourless liquid	bitter almonds	vapour	lethal giddiness, convulsions, unconsciousness, asphyxia	immediate		5000	200,000-1,000,000		France, about 1865, French, 1916	stockpiled by U.S.A. from 1942 on
	HD	distilled mustard	$S(CH_2CH_2Cl)_2$	colourless to amber oily liquid	faint garlic	vapour liquid	harassing eyes: inflammation, photophobia, ulceration, blindness	delayed 1-48 hours	(blisters: 0.032)	1000	>10,000	7 day blindness: 200; 2-week skin burns: 1000	Germans, 1917	most widely stockpiled agent of WW2
	T		$O(CH_2CH_2SCH_2CH_2Cl)_2$	oily liquid	none	liquid aerosol	skin: redness, irritation, blisters	delayed	(blisters: 0.004)	about 400			UK, USA pre-WW2	used mixed with mustard, their production methods yield such mixtures, the British stockpiled 60/40 HT during WW2
	Q	sesqui-mustard	$CH_2SCH_2CH_2Cl$ / $CH_2SCH_2CH_2Cl$	solid	none	aerosol	lethal resembles CG in its action on lungs, other systemic effects	delayed	(blisters: 0.0003)	about 300			UK, USA, Germany, pre-WW2	
	HN3	nitrogen mustard	$N(CH_2CH_2Cl)_3$	colourless to amber, oily liquid	faint geranium smell	vapour liquid aerosol		delayed	(blisters: about 0.06)	1000		7-day blindness: 200; 2-week skin burns: 1000	UK, USA Germany, pre-WW2	less smell than HD, so even more insidious
NERVE GASES	GA	tabun	$(CH_3)_2N\text{-}P(O)(CN)\text{-}OCH_2CH_3$	colourless to dark brown liquid	none to fruity	vapour liquid aerosol	harassing eyes: pupils constrict, vision blurs and dims, eyeballs hurt		1500 (30 'drops')	150		20 (unmasked)	Germany, 1937	standard German tabun contained 20% chlorobenzene; to be aerosol dispersed
	GB	sarin	$CH_3\text{-}P(O)(F)\text{-}OCH(CH_3)_2$	colourless liquid	almost none	vapour liquid	respiration: chest tightness, difficulty in breathing		2000 (40 'drops')	70	15,000	>20 (unmasked)	Germany, 1938	Germans stockpiled large quantities of its intermediates but could make only ½ ton
	GD	soman	$CH_3\text{-}P(O)(F)\text{-}OCH(CH_3)C(CH_3)_3$	liquid	slightly fruity to camphor-like	vapour liquid aerosol		up to 10 min following inhalation, or up to half an hr. following percutaneous absorption	about 1250	about 70			Germany, 1944	highly resistant to oxime therapy
	GE			liquid		vapour liquid aerosol	lethal drooling, sweating, nausea, vomiting, cramps, involuntary defecation or urination, twitching, jerking, staggering, headache, confusion, drowsiness, coma, convulsions, asphyxia						UK, USA Canada late 1940's or early 1950's	
	GF	CMPF	$CH_3\text{-}P(O)(F)\text{-}OCH(CH_2CH_2)_2CH_2$	liquid		liquid vapour aerosol								harder to treat than GB
	VE		$CH_3\text{-}P(O)(OR)\text{-}SCH_2CH_2NR_2$ (R = alkyl)	liquid		liquid aerosol			small					
	VX			liquid		liquid aerosol			small					
HARASSING AGENTS	CA	BBC Camite		pinkish to brown oily liquid	soured fruit	vapour aerosol	harassing burning feeling in mucous membranes, severe eye irritation and lachrymation, headache	immediate		3500		30	French 1918	useful as a persistent harassing agent
	CN	CAP		white crystals	apple blossom	aerosol	harassing burning feeling on moist skin, copious lachrymation	immediate		8500		80	USA 1918	
	DM	adamsite		canary yellow to brownish-green crystals	almost none	aerosol	harassing headache, sneezing, coughing, chest pains, nausea, vomiting	up to 3 minutes		30,000		20	UK, USA 1918	
	CS	OCBM		white crystals	peppery	aerosol	harassing stinging and burning feeling on skin, coughing, tears, chest tightness, nausea	immediate		very large		10	UK early 1950's	
Incapacitating Agent	BZ			solid		aerosol	slowing of physical and mental activity, giddiness, disorientation, hallucinations, occasional maniacal behaviour						USA, middle 1950's	only standardized incapacitating agent by 1963

PRINCIPAL PROPERTIES of the major known chemical weapons are outlined in the table above. Smell and normal physical states vary greatly with the purity of the agent, and lethal and incapacitating concentrations depend on the rate of breathing and the size of the aerosol particles; figures given are for a breathing rate of 15 litres/min (typical of mild activity). Optimum aerosol size, for maximum lung penetration is 0.5 to 3 microns. * defined in glossary

(Rose 1968)

APPENDIX 2

Range of Mission-Oriented Protective Postures (MOPP)

Temperature Range	Work Rate*	Protective Posture
10-21°C (50-70°F)	Low	Wear full protective clothing and equipment.
	Moderate	Wear full protective clothing and equipment.
	Heavy	Remove and carry mask, hood, and gloves. Progressively open and remove some protective clothing.
21-29°C (70-85°F)	Low	Progressively open hood and clothing.
	Moderate	Remove and carry mask, hood, and gloves. Open protective clothing and duty uniform.
	Heavy	Remove and carry mask, hood, and gloves. Remove some protective clothing.
29-38°C (85-100°F)	Low	Remove and carry mask, hood, and gloves. Remove some protective clothing.
	Moderate	Remove and carry mask, hood, and gloves. Remove some protective clothing.
	Heavy	Remove and carry mask, hood, and gloves. Remove protective clothing.

*Examples of work rates:
Low - Motorized movement or administrative work.
Moderate - Improvement of positions or reserve position activity.
Heavy - Infantry dismounted assault or forced march.
Source: U.S. Army (1977).

(Chemical Protective Clothing Systems 1981)

APPENDIX 3

Classification, Medical Aspects, and Prevention of Heat Illness

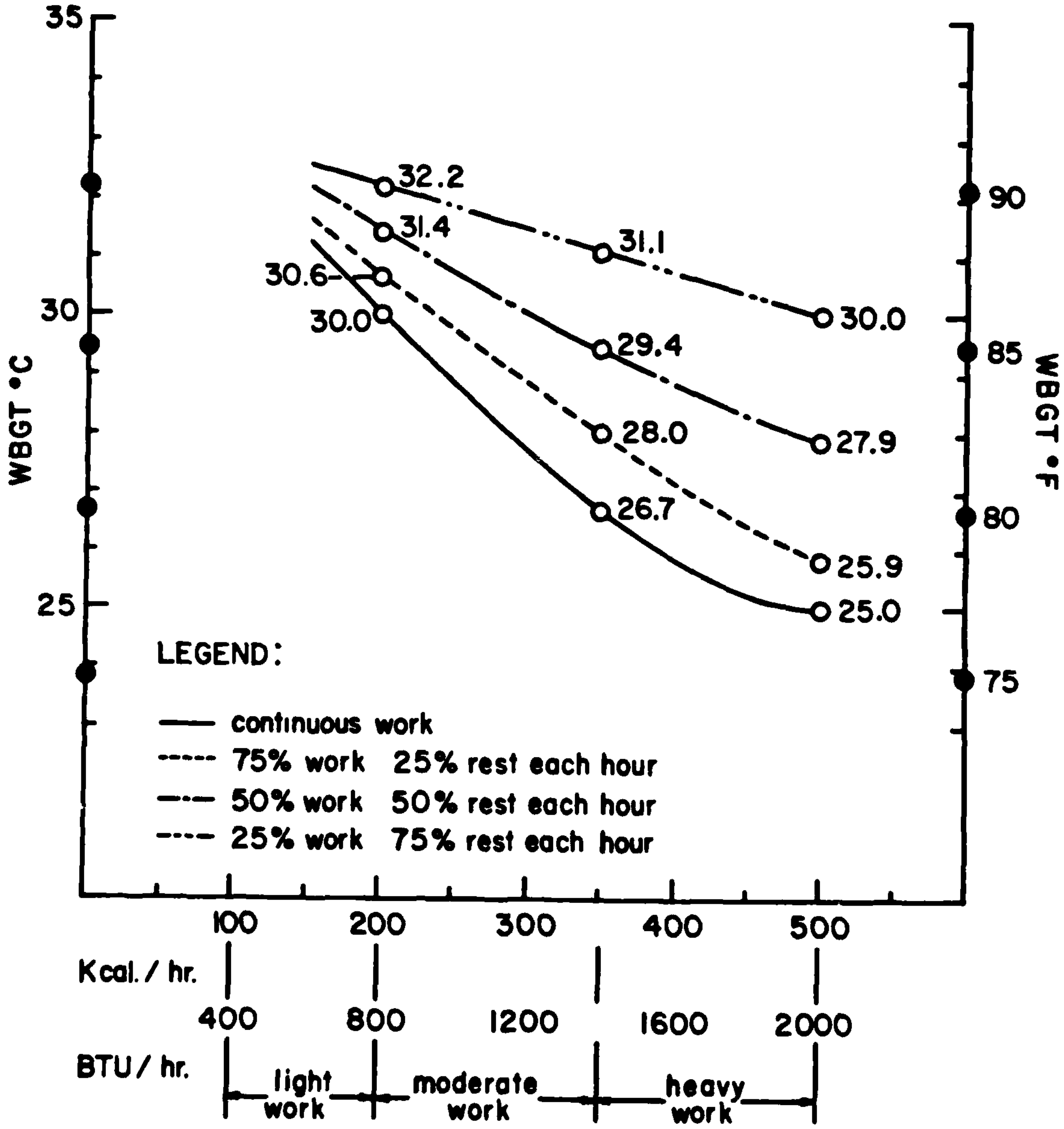
Category	Clinical Features	Predisposing Factors	Underlying Physiological Disturbance	Treatment	Prevention
1. Temperature Regulation					
Heat Stroke and Heat Hyperpyrexia	Heat Stroke: 1) *Hot dry skin*: red, mottled or cyanotic. 2) *High and rising* T_c, 40.5°C and over. 3) *Brain disorders*: mental confusion, loss of consciousness, convulsions, coma as T_c continues to rise. Fatal if treatment delayed. Heat Hyperpyrexia: milder form. T_c lower; less severe brain disorders, some sweating.	1) Sustained exertion in heat by unacclimatized workers. 2) Lack of physical fitness and obesity. 3) Recent alcohol intake. 4) Dehydration. 5) Individual susceptibility. 6) Chronic cardiovascular disease in the elderly.	*Heat Stroke*: Failure of the central drive for sweating (cause unknown) leading to loss of evaporative cooling and an uncontrolled accelerating rise in T_c. *Heat Hyperpyrexia*: Partial rather than complete failure of sweating.	*Heat Stroke*: Immediate and rapid cooling by immersion in chilled water with massage or by wrapping in wet sheet with vigorous fanning with cool dry air. Avoid overcooling. Treat shock if present. *Heat Hyperpyrexia*: Less drastic cooling required if sweating still present and $T_c < 40.5$.	Medical screening of workers. Selection based on health and physical fitness. Acclimatization for 8-14 days by graded work and heat exposure. Monitoring workers during sustained work in severe heat.
2. Circulatory Hypostasis					
Heat Syncope	Fainting while standing erect and immobile in heat.	Lack of acclimatization.	Pooling of blood in dilated vessels of skin and lower parts of body.	Remove to cooler area. Recovery prompt and complete.	Acclimatization. Intermittent activity to assist venous return to heart.
3. Salt and/or Water Depletion					
a) *Heat Exhaustion*	1) Fatigue, nausea, headache, giddiness. 2) Skin clammy and moist. Complexion pale, muddy or hectic flush. 3) May faint on standing with rapid thready pulse and low blood pressure. 4) Oral temperature normal or low but rectal temperature usually elevated (37.5-38.5°C). *Water restriction type*: Urine volume small, highly concentrated. *Salt restriction type*: Urine less concentrated, chlorides less than 3 g/1.	1) Sustained exertion in heat. 2) Lack of acclimatization. 3) Failure to replace water and/or salt lost in sweat.	1) Dehydration from deficiency of water and/or salt intake. 2) Depletion of circulating blood volume. 3) Circulatory strain from competing demands for blood flow to skin and to active muscles.	Remove to cooler environment. Administer salted fluids by mouth or give I-V infusions of normal saline (.9%) if unconscious or vomiting. Keep at rest until urine volume and salt content indicate that salt and water balances have been restored.	Acclimatize workers using a breaking-in schedule for 1 or 2 weeks. Supplement dietary salt only during acclimatization. Ample drinking water to be available at all times and to be taken frequently during work day.
b) *Heat Cramps*	Painful spasms of muscles used during work (arms, legs, or abdominal). Onset during or after work hours.	1) Heavy sweating during hot work. 2) Drinking large volumes of water without replacing salt loss.	Loss of body salt in sweat. Water intake dilutes electrolytes. Water enters muscles, causing spasm.	Salted liquids by mouth, or more prompt relief by I-V infusion.	Adequate salt intake with meals. In unacclimatized men, provide salted (0.1%) drinking water.
4. Skin Eruptions					
a) *Heat Rash* (miliaria rubra; "prickly heat")	Profuse tiny raised red vesicles (blister-like) on affected areas. Pricking sensations during heat exposure.	Unrelieved exposure to humid heat with skin continuously wet with unevaporated sweat.	Plugging of sweat gland ducts with retention of sweat and inflammatory reaction.	Mild drying lotions. Skin cleanliness to prevent infection.	Cooled sleeping quarters to allow skin to dry between heat exposures.
b) *Anhidrotic Heat Exhaustion* (miliaria profunda)	Extensive areas of skin which do not sweat on heat exposure, but present goose flesh appearance, which subsides with cool environments. Associated with incapacitation in heat.	Weeks or months of constant exposure to climatic heat with previous history of extensive heat rash and sunburn. Rarely seen except in troops in wartime.	Skin trauma (heat rash; sunburn) causes sweat retention deep in skin. Reduced evaporative cooling causes heat intolerance.	No effective treatment available for anhidrotic areas of skin. Recovery of sweating occurs gradually on return to cooler climate.	Treat heat rash and avoid further skin trauma by sunburn. Periodic relief from sustained heat.
5. Behavioral Disorders					
a) *Heat Fatigue — Transient*	Impaired performance of skilled sensorimotor, mental, or vigilance tasks, in heat.	Performance decrement greater in unacclimatized, and unskilled men.	Discomfort and physiological strain.	Not indicated unless accompanied by other heat illness.	Acclimatization and training for work in the heat.
b) *Heat Fatigue — Chronic*	Reduced performance capacity. Lowering of self-imposed standards of social behavior (e.g., alcoholic overindulgence). Inability to concentrate, etc.	Workers at risk come from homes in temperate climates, for long residence in tropical latitudes.	Psychosocial stresses probably as important as heat stress. May involve hormonal imbalance but no positive evidence.	Medical treatment for serious cases. Speedy relief of symptoms on returning home.	Orientation on life abroad (customs, climate, living conditions, etc.)

Reprinted from "Heat Stress and Heat Disorders", Leithead, C. S., Lind, A. R., (1964) published by F. A. Davies Co., Philadelphia, Pa.

(The Industrial Environment 1973)

APPENDIX 4

(The Industrial Environment 1973)



American Conference of Governmental Industrial Hygienists: Cincinnati, Ohio, 1971.
Permissible Heat Exposure Threshold Limit Value.

APPENDIX 5

Comparison of anthropometric measurements and maximal cardiac function by decade

Age Range	Sex	n	Ht, cm	Wt, kg	BSA, m^2	$\dot{V}O_2$, $ml \cdot kg^{-1} \cdot min^{-1}$	$\dot{Q}$, $l \cdot min^{-1} \cdot m^{-2}$	HR, beats/min	SV, ml/m^2
20–29	M	6	177	74	1.90	45.4	10.85	196	55
			±6	±6	±0.10	±4.2	±0.68	±12	±6
	F	9	166	59	1.65	37.9	8.81	198	44
			±5	±7	±0.10	±4.2	±0.78	±12	±5
30–39	M	7	182	82	2.04	41.8	10.33	189	54
			±4	±6	±0.09	±5.7	±1.06	[illegible]	±6
	F	33	165	59	1.65	28.3	7.21	[illegible]	29
			±6	±7	±0.12	±3.4	±0.57	±10	±4
40–49	M	35	178	81	1.98	37.7	9.66	181	53
			±8	±11	±0.15	±5.6	±0.95	±11	±6
	F	39	167	65	1.72	25.9	6.88	179	38
			±5	±10	±0.14	±3.3	±0.53	±12	±4
50–59	M	28	177	78	1.95	34.8	9.08	172	53
			±5	±6	±0.09	±6.1	±1.12	±10	±6
	F	22	167	65	1.72	24.7	6.69	177	38
			±7	±11	±0.16	±2.8	±0.45	±12	±4
60–75	M	22	177	79	1.96	28.0	7.84	160	49
			±9	±9	±0.14	±6.9	±1.26	±25	±5
	F	1	159	54	1.54	18.7	5.70	160	35

Values are means ± SD; n, no. of subjects. BSA, body surface area; $\dot{V}O_2$, maximal O_2 uptake; $\dot{Q}$, maximal cardiac index; HR, heart rate; SV, maximal stroke index.

(Hossack and Bruce 1982)

APPENDIX 6

FUNDAMENTALS OF EXERCISE TESTING

RELATIVE MERITS OF EXERCISE TESTS*

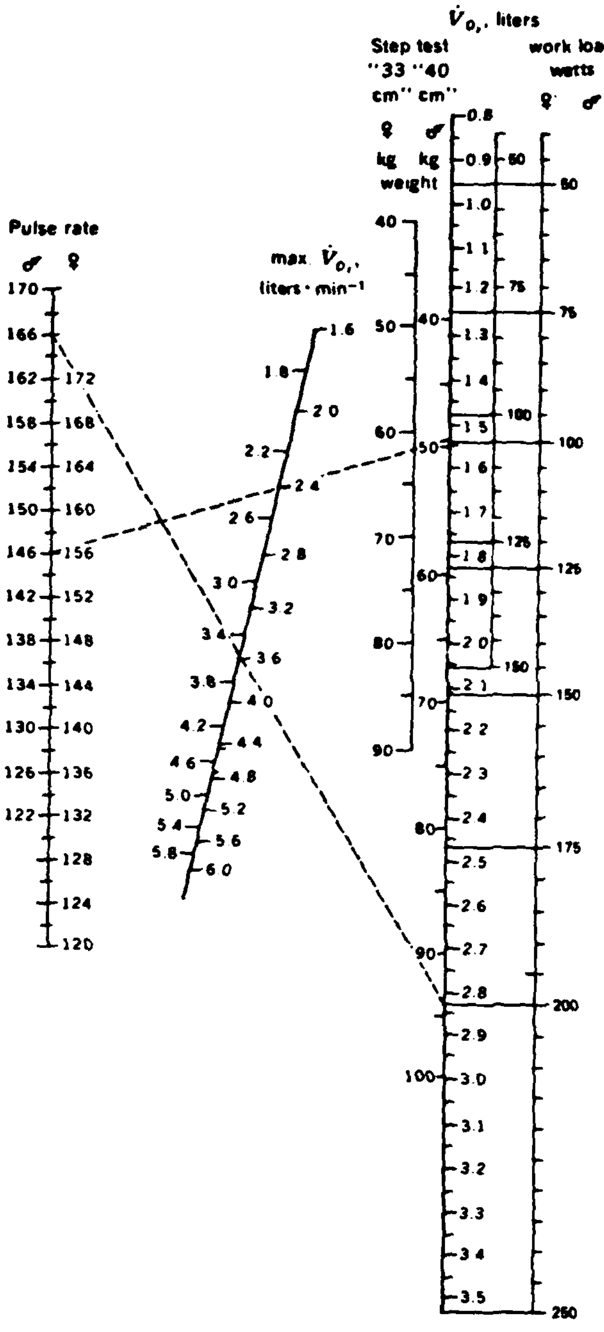
Criterion	Type of test			
	Step	Upright bicycle	Supine bicycle	Treadmill
A. Ease of Performance				
Familiarity with task required?	+ + +	+ +	−	+ + +[a]
Ease of obtaining high oxygen uptake	+ +	+ +	±	+ + +
Subject's performance to maximum oxygen uptake	+	+ +	+	+ + +
Ease of instrument calibration	[b]	+ +[c] − −[d]	+ +[c] − −[d]	+ or ±[e]
Ease of measuring applied power	+ +[f]	+ + +	+ + +[f]	[g]
Ease of recording or obtaining the following during maximum test:				
ECG	±	+ +	+ +	±
Blood pressure	− −	+ +	+ + +	−
Blood samples	− − −	+ +	+ + +	±
Respiratory volume and oxygen	±	+ +	+ +	+
Need for providing for emergency care[h]	+	−	+ + +	− − −
Ease of breathing	+ + +	+ +	+	+ + +
Ease of obtaining a nearly continuous increase of effort[h]	±	+ +[c] + + +[d]	+ +[c] + + +[d]	+ + or ±[a]
B. Freedom from Undesirable Features				
Hazards	+ + + or ±[i]	+	+ + +	− −
Need for skill	+	+	−	+ +[i]
Occurrence of local muscle fatigue at high exercise levels	+	−	− −	+ +
Need for trained personnel	+ +	+ +	+ +	±
Cost of equipment	+ + +	+ +[c] − −[d]	+[c] − −[d]	− − −
Ease of maintenance (including need for constant calibration)	+ + +	+ +[c] ±[d]	+ +[c] ±[d]	±
Freedom from noise	+ + +	±	±	− −
Bulk of equipment[h]	+ + +	+	−	− − −
Ease of transporting equipment[h]	+ + +	+ +[c] ±[d]	±[c], − −[d]	− − −
Need for electricity[h]	[b]	+ +[c] − −[d]	+ +[c] − −[d]	− − −
Need for neuromuscular-skeletal co-ordination	−	−	+	− −
Ease of rate control[h]	− −	−[c] + +[d]	−[c] + +[d]	+ + +

* This table is reproduced from the report of a WHO Meeting on Exercise Tests in Relation to Cardiovascular Function (*Wld Hlth Org. techn. Rep. Ser.*, 1968, No. 388, p. 11). Each of the four types of test is evaluated according to the criteria listed in the first column. A grading of + + + indicates easiest, greatest freedom from undesirable features, most advantageous, etc.; a grading of − − − indicates most difficult, least freedom from undesirable features, least advantageous, etc. The intermediate point is represented by a grading of ±. Throughout the table, therefore, the greater the number of plus signs (or the fewer the number of minus signs), the fewer the problems presented by the test concerned.

[a] More difficult when the rate and slope are high.
[b] Unnecessary.
[c] Friction type.
[d] Electric type.
[e] Calibration easy for angle, less easy for rate.
[f] Less easy at maximum power.
[g] Can be estimated only.
[h] Less important factor.
[i] Less at low stepping rate, greater at high rate.

(Andersen et al. 1971)

APPENDIX 7



The adjusted nomogram for calculation of maximal oxygen uptake from submaximal pulse rate and O_2-uptake values (cycling, running or walking, and step test). In tests without direct O_2-uptake measurement, it can be estimated by reading horizontally from the "body weight" scale (step test) or "work load" scale (cycle test) to the "O_2 uptake" scale. The point on the O_2-uptake scale ($\dot V_{O_2}$, liters) shall be connected with the corresponding point on the pulse rate scale, and the predicted maximal O_2 uptake read on the middle scale. A female subject (61 kg) reaches a heart rate of 156 at step test; predicted max. $\dot V_{O_2}$ = 2.4 liters · min^{-1}. A male subject reaches a heart rate of 166 at cycling test on a work load of 200 watts; predicted max. $\dot V_{O_2}$ = 3.6 liters · min^{-1} (exemplified by dotted lines). *(From I. Åstrand, 1960.)*

(Astrand and Rodahl 1977)

APPENDIX 8

EXPLANATION OF RESEARCH PROJECT

The study you are being asked to participate in will provide important information about the effects of physical conditioning on heat tolerance in chemical defense gear. We hope this information might be used to allow longer wear time or more efficient work output in chemical defense gear in conditions of heat.

1. Explanation of the Graded Exercise Test

You will perform a graded exercise test on a bicycle ergometer. The work levels will begin at a level you can easily accomplish and will be advanced in stages, depending on your work capacity. We may stop the test at any time because of signs of fatigue or you may stop when you wish to because of personal feelings of fatigue or discomfort. We do not wish you to exercise at a level which is abnormally uncomfortable for you.

2. Risks and Discomforts

There exists the possibility of certain changes occurring during the test. They include fainting, disorders of heart beat, and very rare instances of heart attack. Every effort will be made to minimize these dangers by the preliminary examination and by observations during testing. Emergency equipment and trained personnel are available to deal with unusual

situations which may arise.

3. Benefits to be Expected

The results obtained from the exercise test will be used to assess your maximum work capacity. You will be asked to blow in bags during exercise testing for this determination. You will also be asked to exercise with chemical defense gear on to determine how long you can maintain a body temperature that indicates no threat of heat illness as measured by rectal temperatures. This information will be used to determine if heat tolerance time can be increased by physical conditioning thus enabling troops to work longer, or more efficiently in times of a chemical threat.

4. Conducting the experiment

The experiment will consist of dividing the subjects into 2 groups after your work capacity and heat tolerance time in chemical defense gear is tested. One group will attend their technical training classes without any other interventions and will have the above exercise tests repeated at the end of 12 weeks. The other group will also attend their technical training classes, but in addition they will exercise on a bicycle ergometer 1 hour a day for 12 weeks. This will increase physical fitness and thus any increase in heat tolerance will be attributed to this increase in physical fitness. Transportation will be provided to and from all experiments.

5. Confidentially

Assuring your privacy is a promise we make to you.

Confidentiality will be secured in the following manner: at the beginning of the study, you will be assigned a number which will correspond to the last 4 digits of your social security number that only the researcher will have access to. All data and information will be recorded by this number, not your name nor your social security number. The master roster that matches the social security numbers and the assigned number will not be used for any reason except if laboratory data should suggest that an individual has a signficant medical problem. The individual would be notified directly by the researcher and told of the significance of the finding. No other action will be taken. Further evaluation would be up to the individual.

6. Dropping out

If at any time you want to drop out of the study, you can. You will not be penalized in any way. None of the study results can be used in any way against you. Your participation is entirely voluntary. No information will be given out to anyone.

7. Inquiries

Any questions about the procedures used in anything connected with this experiment are welcome at any time. If you have any doubts or questions, please ask us for further explanations.

8. Incentive

A base-of-preference will be given to each participant who completes this experiment. This base will be chosen

from the list of available bases within a particular AFSC.

9. Freedom of Consent

Permission for you to perform this experiment is voluntary. You are free to deny consent if you so desire. If you choose to participate in this experiment a witnessed consent form will be signed which does not mean you cannot drop out at any time. Thank you for taking time to read this letter.

APPENDIX 9

Sample Consent Form

I, ____, having full capacity to consent, do hereby volunteer to participate in a research study entitled: The Effects of Physical Conditioning on Heat Tolerance in Chemical Defense Gear under the direction of Michelle M. Nauss. The implications of my voluntary participation; the nature, duration and purpose; the means and methods by which it is to be conducted; and the inconveniences and hazards which may reasonably be expected have been explained to by Michelle M. Nauss, and are set forth on the reverse side of this agreement, which I have initialed. I have been given an opportunity to ask questions concerning this research project, and any such questions have been answered to my full and complete satisfaction. I understand that I may at any time during the course of this project revoke my consent, and withdraw from the project without prejudice; however, I may be required to undergo certain further examinations, if in the opinion of the attending physician, such examinations are necessary for my health and well-being. I understand that privacy and confidentiality will be maintained at all costs in the manner described on the reverse side of this agreement. I further understand that information gained from this study may be used for publication while preserving confidentiality. I have read this form and the "Explanation of the Research Project" and understand the test procedures that I will perform and I consent to participate in this test.

____

signature   date

I was present during the explantion referred to above, as well as the volunter's opportunity for questions, and hereby witness the signature.

____

signature   date

APPENDIX 10

MAXIMUM WEIGHT STANDARDS

Height	Weight (Male)	Weight (Female)
58		126
59		128
60	153	130
61	155	132
62	158	134
63	160	136
64	164	139
65	169	144
66	174	148
67	179	152
68	184	156
69	189	161
70	194	165
71	199	169
72	205	174
73	211	179
74	218	185
75	224	190
76	230	196
77	236	201
78	242	206
79	248	211
80	254	216

(AFIT 1985)

APPENDIX 11

Medical Referral Form for Participation in Graded Exercise Test and Exercise Program

Patient's Name ______________________ Date________
Last First Initial

Address ____________________ Age ____ Phone ______

I consider the above individual as:

__ Normal
__ Cardiac Patient
__ Prone to Coronary Heart Disease
__ Other (Explain) ____

Diagnostic Data Etiologic	*Present Physical Activity*	*ECG*	*Rhythm*
1. No heart disease	1. Very active	1. Normal	1. Sinus
2. Rheumatic heart disease	2. Normal	2. Dig. Effect Only	2. Atrial fib.
3. Congenital heart disease	3. Limited	3. Abnormal	3. Other
4. Hypertension	4. Very limited	4. Infarct	
5. Ischemic heart disease			
6. Other			

Please fill in the information

1. Urine, sp.gr.____ Alb.____ Glucose____ Micro.____
2. Complete blood count: Hbg.__ Hct.__ WBC__ Diff.__
3. ECG, 12 lead (enclose copy) ______________
4. Blood pressure, syst.__diast.__
5. Glucose______mg.%
6. 2 Hr. Post Dexicola______mg.%
7. Cholesterol____mg.% Lipoprotein Electrophoresis____
   Triglyceride____mg.%

Specific Cardiac Diagnosis ______________________

Additional Abnormalities you are aware of ______________

Date of Last Complete Physical Examination __________

Present Medication ______________________

The above listed person is capable of participating in an exercise program as well as periodic laboratory evaluations, under the guidance and supervision of a

( ) Physician
( ) Exercise Leader (____) Check appropriate supervision (____).

Signed:______________________M.D.

Type or Print
Name of Physician______________

APPENDIX 12

RANDOM NUMBER TABLE

00439	81846	45446	93971	84217	74968	62758	49813	13666	12981
29676	37909	95673	66757	72420	40567	81119	87494	85471	81520
69386	71708	88608	67251	22512	00169	58624	04059	05557	73345
68381	61725	49122	75836	15368	52551	54604	61136	51996	19921
69158	38683	41374	17028	09304	10834	61546	33503	84277	44800
00858	04352	17833	41105	46569	90109	14713	15905	84555	92326
86972	51707	58242	16035	94887	83510	56462	83759	68279	64873
30606	45225	30161	07973	03034	82983	78242	06519	96345	53424
93864	49044	57169	43125	11703	87009	76463	48263	99273	79449
61937	90217	56708	35351	60820	90729	90472	68749	23171	67640
94551	69538	52924	08530	79302	34981	12155	42714	39810	92772
79385	49498	48569	57888	70564	17660	50411	19640	07597	34550
14796	51195	69638	55111	06883	13761	53688	44212	71380	56294
79793	05845	58100	24112	26866	26299	74127	63514	04218	07584
98488	68394	65390	41384	52188	81868	74272	77608	34806	46529
96773	24159	28290	31915	30365	06082	73440	16701	78019	49144
18849	96248	46509	56863	27018	64818	40938	66102	65833	39169
71447	27337	62158	25679	63325	98699	16926	28929	06692	05049
97091	42397	08406	04213	52727	08328	24057	78695	91207	18451
56644	52133	55069	57102	67821	54934	66318	35153	36755	88011
60138	40435	75526	35949	84558	13211	29579	30084	47671	44720
80089	48271	45519	64328	48167	14794	07440	53407	32341	30360
54302	81734	15723	10921	20123	02787	97407	02481	69785	58025
61763	77188	54997	28352	57192	22751	82470	92971	29091	35441
25769	28265	26135	52688	11867	05398	43797	45228	28086	84568
80142	64567	38915	40716	76797	37083	53872	30022	43767	60257
69481	57748	93003	99900	25413	64661	17132	53464	52705	69602
40431	28106	28655	84536	71208	47599	36136	46412	99748	76167
16264	39564	37178	61382	51274	89407	11283	77207	90547	50981
19618	87653	18682	22917	56801	81679	93285	68284	11203	47990

(Kuzma 1984)

BIBLIOGRAPHY

Adolph, E.F. Physiology of Man in the Desert. New York: Hafner Publishing Company, 1969.

Air Force Institute of Technology, Civilian Institution Programs Student Regulation. Department of the Air Force Air University, 1 January 1985.

American College of Sports Medicine. Guidelines for Graded Exercise Testing and Exercise Prescription. Philadelphia, 1975.

Andersen, K.L.; Shephard R.J.; Denolin, H.; Varnauskas, E.; and Maseroni R. Fundamentals of Exercise Testing. Belgium: WHO, 1971.

Astrand, P.O. and Rodahl, K. Textbook of Work Physiology. New York: McGraw-Hill Book Company, 1977.

Bass, D.E.; Kluman, C.R.; Quinn, M.; Henschell A., and Hegnauer, A.H. "Mechanisms of Acclimitization to Heat in Man." Medicine, 34: 323-380, 1955.

Baxter, C.R. "Prevention, Recognition and Treatment of Heat Disorder." Texas State Journal of Medicine, 60: 746-753, 1964.

Bean, W.B. and Eichna, L.W. "Performance in Relation to Environmental Temperature." Federal Proceeding, 2: 144-158, 1943.

Belding, H.S. "Hazards to Health, Work in Hot Weather." The New England Journal of Medicine, 266: 1052-1054, 1962.

Buchsbaum, R.; Pechersky, J.; McKibben, D. Report on the Effects of Heat Stress on Cellular Structure and Function. Wright-Patterson AFB, Ohio: Aerospace Medical Research Laboratory, [February 1970].

Chemical Protective Clothing Systems. ABMPS Report No. 104, [September 1981].

Eichna, L.W.; Park, C.R.; Nelson, N.; Horvath, S.M.; and Palmes, E.D. "Thermal Regulation During Acclimitization in a Hot Dry (Desert Type) Environment." The American Journal of Physiology, 163: 585-597, 1950.

Eifler, C.W. "Sample Size Necessary to Obtain a Desired Precision." Handout 13. Fall 1985.

Ellis, F.P.; Ferres, H.M.; and Lind, A.R. "The Effect of Water Intake on Sweat Production in Hot environments." Journal of Physiology, 25: 61P, 1954.

Epstein, S.E.; Robinson, B.F.; Kahler, R.L.; and Braunwal, E. "Effects of Beta-Adrenergic Blockade on the Cardiac Response to Maximal and Submaximal Exercise in Man." Journal of Clinical Investigation, 44: 1745-1753, 1965.

"Exertional Heat Injury." Medical Letter on Drugs and Therapeutics, 27 (690): 55-56, 21 June 1985.

Fox, R.H. "Heat Stress and Athletics." Ergonomics, 3: 307-313, 1960.

Frisancho, A.R. Human Adaptation--A Functional Interpretation. Ann Arbor: The University of Michigan Press, 1981.

Fruth, J.M. and Gisolfi, C.V. "Work-heat Tolerance in Endurance Trained Rats." Journal of Applied Physiology, 54 (1): 249-253, June 1983.

Gisolfi, C.V. "Work-heat Tolerance Derived From Interval Training." Journal of Applied Physiology, 35: 349-353, September 1973.

Gripstad, B. Chemical Warfare Agents. Nils-Henrik Lundquist Publisher: June 1983.

Guyton, A.C. Basic Human Physiology: Normal Functional and Mechanisms of Disease. Philadelphia: W.B. Saunders Co., 1977.

Hoppeler, H.; Howard, H.; Conley, K.; Lindstedt, S.L.; Claasen, H.; Vock, P.; and Weibel, E.R. "Endurance Training in Humans: Aerobic Capacity and Structure of Skeletal Muscle." Journal Applied Physiology, 59 (2): 320-327, Aug 1985.

Hossack, K.F. and Bruce, R.A. "Maximal Cardiac Function in Sedentary Normal Men and Women: Comparison of Age-Related Changes." Journal of Applied Physiology, 53: 799-804, 1982.

Houston, C.S. and Riley, R.L. "Respiratory and Circulatory Changes During Acclimitization to High Altitude." The American Journal of Physiology, 149: 565-588, 1947.

The Industrial Environment--its Evaluation and Control. U.S. Department of Health, Education, and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, 1973.

Knox, F.S.; Nagel, G.A.; Hamilton, B.E.; Olazabal, R.P.; and Kimball, K.A. Report on the Physiological Impact on Wearing Aircrew Chemical Defense Protective Ensembles While Flying the UH-IH in Hot Weather. Fort Rucker, Alabama: Biomedical Applications Research Division, [October 1982].

Kuzma, J.W. Basic Statistics for the Health Sciences. California: Mayfield Publishing Company, 1984.

Ladell, W.S., "The Changes in Water and Chloride Distribution During Heavy Sweating." Journal of Physiology, 108: 440-450, 1949.

Lind, A.R. and Bass, D.E. "Optimal Exposure Time for Development of Acclimatization to Heat." Federation Proceeding, 22: 704-708, 1963.

Murphy, R.P. and Ashe, W.F. "Prevention of Heat Illness in Football Players." Journal of the American Medical Association, 194: 650-654, 1965.

Myles, W.S. and Chin A.K. Report on the Physical Fitness and Tolerance to Environmental Stresses: A Review of Human Research on Tolerance to and Work Capacity in Hot, Cold a:nd High Altitude Environments. Defense and Civil Institute of Environmental Medicine: Ontario, [2 July 1979].

Pitts, G.C., Johnson, R.E., and Consolazio, F.C. "Work in the Heat as Affected by Intake of Water, Salt and Glucose." American Journal of Physiology, 142: 253-259, 1944.

Piwonka, R.W. and Robinson, S. "Acclimitization of Highly Trained Men to Work in Severe Heat." Journal of Applied Physiology, 22: 9-12, 1967.

Rose, S. Chemical and Biological Warfare. Beacon Press: Boston, 1968.

Riegelman, R.K. Studying a Study and Testing a Test. Little, Brown and Co.: Boston, 1981.

Senay, L.C. and Christensen, M.L. "Variations of Certain Blood Constituents During Acute Heat Exposure." Journal of Applied Physiology, 24: 302-309, 1968.

Victor, L.D. and Chmielinski, M.A. "Pulmonary Function and Exercise Stress Testing." Hospital Practice, 125-130, Jul 1982.

Winslow, C.E. and Gagge, A.P. "Influence of Physical Work on Physiological Reactions to the Thermal Environment." American Journal of Physiology, 134: 664-681, 1941.

Wyndham, C.H., "Effect of Acclimatization on the Sweat Rate/Rectal Temperature Relationship," Journal of Applied Physiology, 22: 27-30, 1967.

Yates, R.E.; Replogle, C.R.; and Veghte, J.H. Report on Thermal and Accleration Effects on Aircrew Members in Chemical Defense Gear. Wright-Patterson AFB, Ohio: Air Force Aerospace Medical Research Laboratory, [January 1980].

VITA

Michelle Marie Nauss was born in Ankara, Turkey, on January 28 1958, the daughter of Jacqueline Doris Nauss and Donald Nauss. After graduating second in her class at Fairfield High School, Fairfield, California, in 1976, she entered California State University, Sacramento, at Sacramento, California. During the summers of 1977 and 1978, and the academic year 1978-1979, she attended Solano Community College where she received an associate of science degree. She graduated Magna Cum Laude at California State University, Chico receiving the degree of Bachelor of Science in Nursing in December 1981 and was inducted into Sigma Theta Tau, the honor society of nursing. In April 1982 she was commissioned a second lieutenant in the United States Air Force Nurse Corps. From August 1982 to January 1983, she served a nurse internship at Wilford Hall Medical Center, San Antonio, Texas. After completion of this internship, she served as a staff nurse on the obstetrical ward at Holloman AFB, Alamogordo, New Mexico until February 1984. From March 1984 until August 1985 she served in the same capacity at Incirlik AB, Turkey. In September 1985 she entered the School of Public Health at The University of Texas Health Science Center at Houston and plans to graduate June 1986 with a Master of Public Health degree. In September she will continue her Air Force career as an Environmental Health Nurse.

Permanent address: 7710 Oakdell Way #503
San Antonio, Texas 78240

This project was typed by Michelle M. Nauss.

ATE

LMED

-8